

Seasonal incidence and management of *Varroa destructor* (Anderson and Trueman) in *Apis mellifera* L. colonies of Kangra Valley of Himachal Pradesh

Sapna Devi*, Dipanshi Bhardwaj, Payal Thakur

Department of Zoology, Sri Sai University, Himachal Pradesh, India

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Abstract

The present investigation entitled “Seasonal incidence and management of *Varroa destructor* (Anderson and Trueman) in *Apis mellifera* L. Colonies of Kangra valley of Himachal Pradesh” carried out from July 2024 to June 2025 in the Kangra valley of Himachal Pradesh (stationary conditions) and migratory regions of Anupgarh, Rajasthan, aimed to study the seasonal incidence and management of significant ectoparasitic mite *Varroa destructor* in *Apis mellifera* colonies. Comprehensive monthly observations were recorded under both stationary and migratory setups. The infestation patterns of *Varroa destructor* closely followed the seasonal trends, with maximum infestation observed during June and a sharp reduction during colder months, attributed to limited brood availability and lower ambient temperatures. In *Varroa destructor*, the highest levels of infestation was recorded in June under both conditions, with sticky paper, brood infestation, and per hundred bee count methods indicating 46.00 mites/colony, 48.20% brood infestation, and 44.60 mites/100 bees, respectively. Evaluation of management strategies using plant-based essential oils demonstrated that Thyme oil was most effective in controlling *V. destructor*, reducing brood infestation from 48.00% to 5.66% across three applications. Cinnamon, Peppermint, and Rosemary oils also showed moderate efficacy. These findings highlight the significant influence of seasonal variations on mite population dynamics and validate the potential use of essential oils particularly Thyme is as effective, sustainable, and eco-friendly alternatives to conventional chemical acaricides for the management of *Varroa destructor* in *Apis mellifera* colonies.

Keywords: Stationary conditions, migratory conditions, sticky paper method, brood infestation, per hundred bee method, plant based essential oils

Introduction

In India, beekeeping is primarily practiced with domesticated species such as *Apis cerana* and *Apis mellifera*. The rearing of *Apis cerana* is predominantly done in southern India, as well as in selected regions of northern and northeastern India. In contrast, *Apis mellifera* is mainly reared in the Indo-Gangetic plains, covering states like Punjab, Jammu and Kashmir, Himachal Pradesh, Odisha, Uttarakhand, Kerala, Uttar Pradesh, Bihar, and West Bengal. The leading honey-producing states are Punjab, Himachal Pradesh, Jammu and Kashmir, Assam, and Bihar (Gatoria *et al.*, 2005) [13]. Honey is renowned for boosting physical performance and enhancing resistance to fatigue, especially during prolonged exertion. It is also linked to improved mental clarity and efficiency. As a result, honey is consumed by both the healthy and the ill to combat various forms of weakness. Some of its health benefits include aiding in the growth of infants, improving calcium absorption in bones, and helping to treat anemia and anorexia (Krell, 2001) [18]. Additionally, honey is believed to support better digestion and is useful for chronic intestinal issues, including constipation, duodenal ulcers, coughs, and liver ailments. Honey bees are susceptible to variety of environmental threats. There is not only a single factor but several abiotic and biotic factors which acts alone or in combination to cause potential mortality in colonies. Honey bees are also susceptible to attack of various natural enemies including different pathogens, parasites and pests. These enemies have a negative influence on the production

and performance of colonies. Appearance of these bee enemies results into widespread destruction of honey bee colonies. The presence of bee products like honey, bee wax, brood, pollen, nectar and favourable environmental conditions available in the hive invites a number of natural enemies and diseases, which also affects the health of honey bee colonies and honey bees and make them too weak to exist (Chen *et al.*, 2006) [6]. Introduction of the European honey bee (*Apis mellifera* L.) to Asia increased the overall number of distinct bee species in the region. However, new pathogens, such as *Acarapis woodi*, were also brought into Asia with the arrival of the European honey bee. Additionally, parasites like *Varroa destructor* were also shifted from their original hosts to the new honey bee species. This has significantly changed the landscape of honey bee diseases for *Apis mellifera* in Asia and worldwide. The mite, *Varroa destructor* Anderson and Trueman, has become a major problem for beekeeping with European honey bees (*Apis mellifera*) almost worldwide. In recent years, *V. destructor* has vanished thousands of bee colonies in various parts of the world (De Jong, 1997) [9]. *Varroa destructor*, previously known as *Varroa jacobsoni*, was first identified in Java in 1904 on the Asian honey bee, *Apis cerana*. *Varroa destructor* belongs to class Arachnida. *Varroa* mite is considered as one of the most dangerous pest of honey bee and it is highly destructive as it feeds ectoparasitically on bee larvae and adult bee body. The parasite was reported to be associated with *Apis mellifera* (Italian honey bee) for the first time in 1962, marking the

beginning of a new host-parasite relationship. In India, *Varroa jacobsoni* was initially recorded in *A. cerana* colonies in Pusa, Delhi (Phadke *et al.*, 1966)^[22], and later in *A. cerana* colonies in Jammu and Kashmir (Punjabi and Saraf, 1969)^[23]. The first report of *Varroa destructor* infestation in *A. mellifera* colonies was reported in Kangra district of Himachal Pradesh, India in 1988 (Kumar *et al.*, 1988)^[19]. The mite was also observed in Punjab by the end of 2004 (Gatoria *et al.*, 2005)^[13] and spread rapidly throughout the state by the mid of 2005 (Chhuneja *et al.*, 2006)^[8, 13]. It caused significant damage to *A. mellifera* colonies across several regions, including Jammu and Kashmir, Himachal Pradesh, Punjab, Haryana, Delhi, Rajasthan, Uttar Pradesh, and Uttarakhand, and was quickly advancing toward Bihar and West Bengal (Chhuneja, 2008)^[7]. Approximately 90% of apiaries and 50% of colonies have been affected by this mite (Gulati *et al.*, 2009)^[15]. *Varroa destructor* feeds on the haemolymph of both adult and developing bees, typically surviving for 7-13 days on adult bees (Schulz, 1984)^[25]. The infestation will cause direct damage to honey bees by reducing their body weight and shortening the lifespan (De Jong *et al.*, 1982)^[10]. The present study therefore, deals with the seasonal incidence of *Varroa destructor* and various management strategies against *Varroa destructor* in Kangra Valley of Himachal Pradesh.

Material Method

The present study entitled “Seasonal Incidence and Management of *Varroa destructor* (Anderson and Trueman) in *Apis mellifera* L. Colonies of Kangra Valley of Himachal Pradesh” was carried out from July 2024 to June 2025. The experiment was conducted at two locations: a stationary apiary situated at Jandpur, Palampur in Kangra district, Himachal Pradesh, and a migratory apiary located at Anupgarh in Rajasthan. These sites were selected to represent distinct climatic and ecological conditions—temperate and semi-arid respectively—allowing for an evaluation of seasonal variations in mite infestation and colony development. To assess the seasonal incidence of *V. destructor*, three standardized methods were employed. The sticky paper method involved placing mustard oil-coated white paper sheets on the hive’s bottom board to trap falling mites. These sheets were divided into grid squares to facilitate counting, replaced weekly, and examined under a magnifying lens to record mite counts (Delaplane and Hood, 1999)^[11]. In the visual examination method, 100 brood cells were inspected from each colony using a hand lens to determine percent infestation. Additionally, in the powdered sugar shake method (per hundred bees method), 100 bees were sampled from the brood nest of each colony, dusted with powdered sugar, and shaken in a jar to dislodge mites. After mild agitation, mites falling onto a white paper surface were counted (Ostiguy *et al.*, 2000)^[21]. To investigate the influence of environmental variables on mite infestation, weather data including maximum and minimum temperature, relative humidity, and rainfall were collected from online meteorological sources corresponding to the experimental period. These parameters were correlated with

recorded mite populations, brood area, and colony strength to assess the seasonal dynamics of mite incidence and possible climatic influences. For the management of *V. destructor*, colonies were initially screened for pre-treatment mite infestation using sticky paper counts and brood cell examination. Seven treatments including six plant-based essential oils and a control were evaluated for each mite species. The essential oils were administered by placing 5 ml of oil-soaked cotton in a Petri dish positioned on the bottom board of the hive. A thick white paper was also placed beneath the frames to catch fallen mites. Treatments were replicated thrice, each in a separate hive containing nine frames. Post-treatment observations were recorded on the 7th, 14th, and 21st days. Sticky papers were replaced at each interval, and the number of mites dislodged post-treatment was recorded to assess treatment efficacy. For *V. destructor*, the oils tested included thyme (*Thymus vulgaris*), cinnamon (*Cinnamomum verum*), rosemary (*Rosmarinus officinalis*), tea tree (*Melaleuca alternifolia*), peppermint (*Mentha piperita*), and clove bud (*Syzygium aromaticum*).

Percent brood infestation was calculated using the formula:

$$\text{Per cent brood infestation} = \frac{\text{No. of cells with mites} \times 100}{\text{Total no. of cells observed}}$$

Reduction (%) in infestation was calculated by using equation given by Henderson and Tilton (1955)^[16]

$$\% = (1 - (n \text{ in } C_o \text{ before treatment} / n \text{ in } T \text{ after treatment}) / (n \text{ in } C_o \text{ after treatment} / n \text{ in } T \text{ before treatment}))$$

Statistical analysis of the collected data was performed using Randomized Block Design (RBD) as described by Gomez and Gomez (1986)^[14] to evaluate the significance of treatment effects.

Result and Discussion

The present study evaluated the seasonal dynamics of *Varroa destructor* infestation in *Apis mellifera* colonies maintained under stationary conditions (Palampur, Himachal Pradesh) and migratory conditions (Anupgarh, Rajasthan) from July 2024 to June 2025 using three standard estimation methods: sticky paper trap (mites/colony), brood infestation (%), and per hundred bee method. Infestation levels peaked in June 2025 across all methods: 46.00 mites/colony (sticky paper), 48.20% (brood infestation), and 44.60 mites/100 bees. These peaks coincided with high colony strength (6.15 bee frames), brood area (2,235.53 cm²), and warm, humid weather (30.0°C max temp, 127 mm rainfall, 50% RH). Significant reductions were recorded from November to January, with no detectable mite presence, correlating with reduced brood and lower temperatures. A significant negative correlation was observed between mite incidence and colony strength ($r = -0.584$ to -0.534) and maximum temperature ($r = -0.362$ to -0.363), while brood area showed a positive correlation ($r = 0.364$). These results suggest that weaker colonies and warmer conditions might suppress mite populations, while larger brood areas may favour reproduction.

Table 1: Seasonal Incidence of *Varroa destructor* in *Apis mellifera* colonies under stationary conditions during 2024-2025 at Palampur, Kangra

period	Incidence of <i>Varroa destructor</i>			Colony parameters		Weather parameters			
	Sticky paper method (no./colony)	Brood infestation (%)	Per hundred Bee method (no.)	Colony strength (bee frame)	Brood area (cm ²)	Temperature		Rainfall (mm)	Relative humidity (%)
						Max.	Min.		
July, 2024	40.00 (6.37)*	41.40 (6.50)	29.00 (5.46)	5.05	1,594.09 (39.93)	26.5	20.5	410	77.4
August	23.00 (4.89)	24.00 (4.98)	19.60 (4.51)	4.85	851.40 (29.16)	25.8	20.0	488	87.4
September	16.40 (4.16)	14.60 (3.92)	12.00 (3.58)	4.65	926.86 (30.44)	25.0	18.5	173	83.0
October	8.60 (3.09)	7.60 (2.91)	7.60 (2.93)	4.45	810.32 (28.43)	23.5	14.0	21	73.0
November	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	3.95	504.81 (22.46)	20.0	11.0	27	71.0
December	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	3.25	406.25 (20.06)	16.0	5.0	45	81.0
January, 2025	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	2.90	430.10 (20.50)	12.0	4.0	85	85.0
February	6.40 (2.71)	4.40 (2.28)	5.80 (2.56)	3.05	949.03 (30.72)	17.0	6.0	83	78.0
March	10.60 (3.40)	12.00 (3.59)	9.20 (3.18)	4.45	1,020.54 (31.91)	18.0	8.0	83	71.0
April	30.80 (5.62)	29.60 (5.52)	25.60 (5.07)	5.50	2,106.90 (45.62)	23.0	12.0	77	51.0
May	38.80 (6.29)	35.20 (6.00)	37.20 (6.17)	6.30	3,175.31 (55.90)	27.0	15.0	57	45.1
June	46.00 (6.84)	48.20 (6.99)	44.60 (6.74)	6.15	2,235.53 (47.26)	30.0	18.0	127	50.0
C.D.	0.37	0.39	0.53	0.49	4.50	-	-	-	-

*Figures are square root transformed values

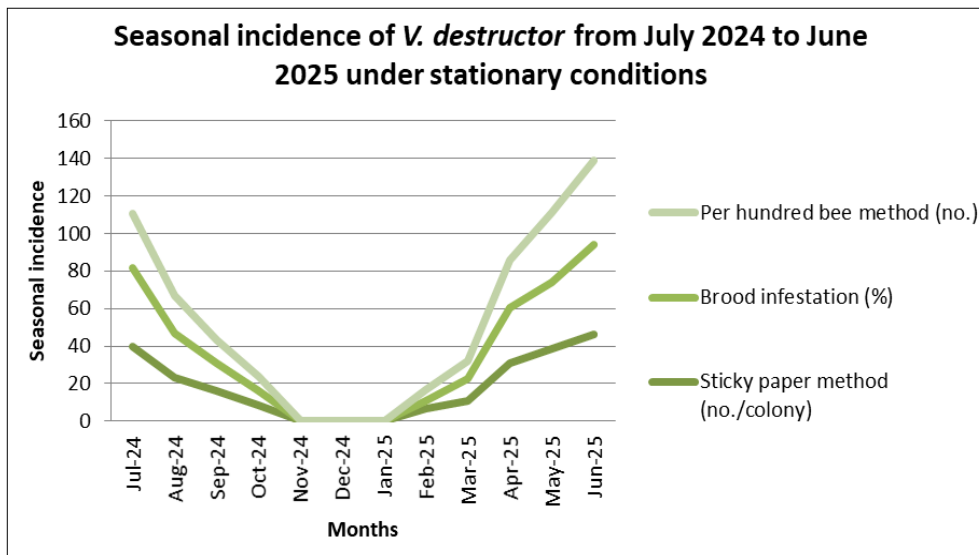


Fig 1: Seasonal incidence of *V. destructor* from July 2024 to June 2025 under stationary conditions

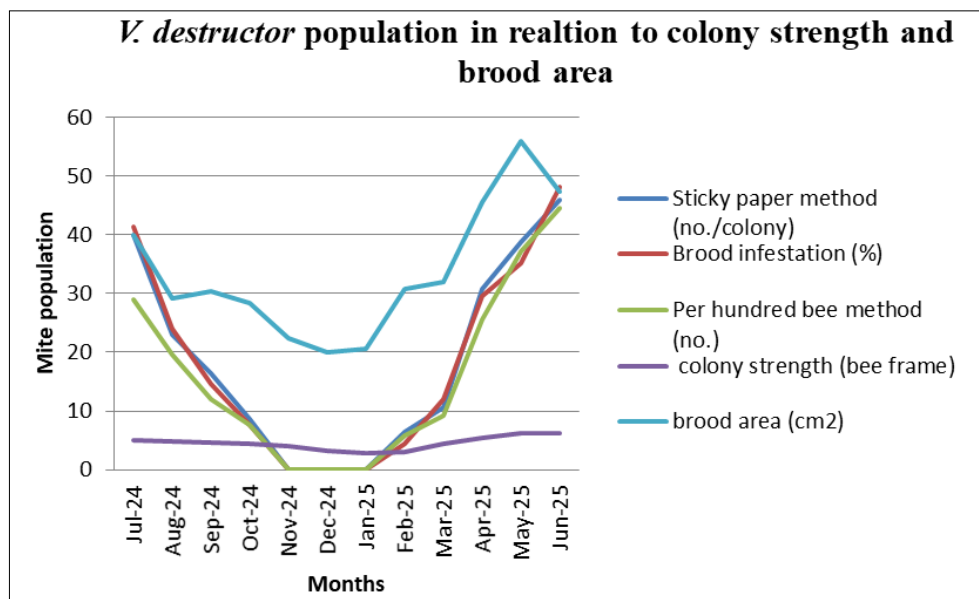


Fig 2: *V. destructor* population in relation to colony strength and brood area

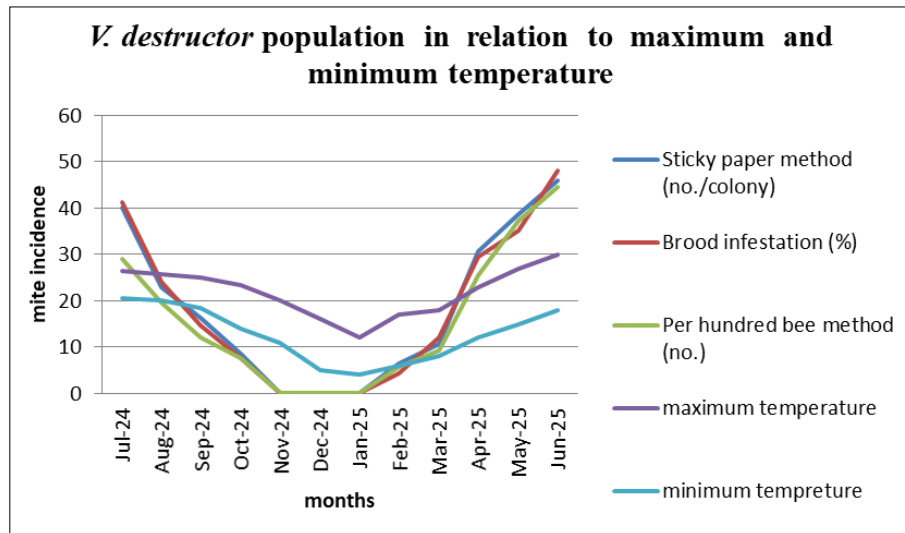


Fig 3: *V. destructor* population in relation to maximum and minimum temperature

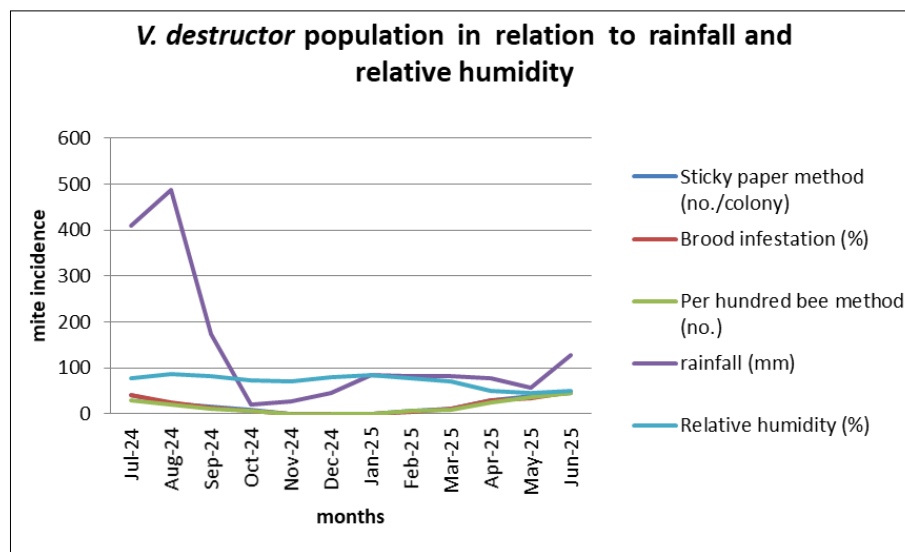


Fig 4: *V. destructor* population in relation to rainfall and relative humidity

Table 2: Pearson correlation coefficient (r) between incidence of *Varroa destructor* with colony and weather parameters under stationary conditions

Parameters \ Methods	Sticky paper method	Brood infestation	Per hundred bee method
Max. temperature	-0.362	-0.353	-0.363
Min. temperature	0.074	0.095	0.146
Rainfall	0.259	0.270	0.062
Relative humidity	0.084	0.093	-0.012
Colony strength	-0.584	-0.590	-0.534
Brood area	0.364	0.364	0.364

Under migratory conditions, peak infestation was also observed in June: 43.40 mites/colony (sticky paper), 46.20% (brood infestation), and 42.00 mites/100 bees. Similar to stationary conditions, mite loads dropped significantly during the cooler months (December–February), aligning with decreased brood rearing and lower temperatures. However, in contrast to stationary conditions, mite incidence here showed a strong positive correlation with colony strength ($r = 0.886\text{--}0.887$) and minimum temperature ($r = 0.336\text{--}0.425$), and a significant negative correlation with brood area ($r = -0.601$ to -0.610). This suggests that stronger colonies in migratory conditions may harbor more mites due to increased availability of hosts,

whereas large brood areas might temporarily dilute mite load per brood cell or reflect efficient hygienic behavior. Mite populations followed a similar seasonal pattern in both regions, peaking during late spring and early summer (May–June), consistent with increased brood availability and conducive environmental conditions. Infestation levels declined sharply during the winter months, likely due to reduced brood and suboptimal temperatures. These observations are consistent with previous findings by Asha *et al.* (2009, 2013), Mattu and Sharma (2016), Brar *et al.* (2018), and Singh *et al.* (2015) [2, 3, 4, 20, 26], who noted higher infestations during warmer months and minimal or no infestation during winter.

Table 3: Seasonal Incidence of *Varroa destructor* in *Apis mellifera* colonies under migratory conditions during July, 2024- June, 2025 at Anupgarh, Rajasthan and Palampur, Kangra

Period	Incidence of <i>Varroa destructor</i>			Colony parameters		Weather parameters			
	Sticky paper method (no./colony)	Brood infestation (%)	Per hundred Bee method (no.)	Colony strength (bee frame)	Brood area (cm ²)	Temperature		Rainfall (mm)	Relative humidity (%)
						Max.	Min.		
July, 2024	39.00 (6.30)*	40.20 (6.41)	27.60 (5.33)	5.15	1,618.26 (40.23)*	26.5	20.5	410	77.4
August	22.20 (4.80)	24.80 (5.05)	18.60 (4.42)	4.55	876.36 (29.57)	25.8	20.0	488	87.4
September	15.20 (4.02)	14.20 (3.87)	10.60 (3.36)	4.65	916.47 (30.26)	25.0	18.5	173	83.0
October	7.80 (2.96)	7.20 (2.81)	6.20 (2.68)	4.50	794.82 (28.14)	23.5	14.0	21	73.0
November**	9.20 (3.18)	8.20 (3.00)	5.40 (2.52)	4.75	875.38 (29.22)	27.5	12.5	1.3	41.5
December**	6.20 (2.67)	6.20 (2.67)	4.20 (2.26)	4.85	1,633.61 (39.52)	23.7	8.3	1.3	46.5
January, 2025**	9.00 (3.15)	9.20 (3.18)	8.20 (3.02)	5.35	2,131.05 (46.16)	22.3	8.7	1.2	51.5
February**	11.60 (3.54)	10.20 (3.32)	10.40 (3.37)	7.15	3,283.37 (53.46)	24.7	11.3	3.7	46.6
March**	13.00 (3.73)	14.60 (3.93)	11.80 (3.57)	8.30	5,153.56 (65.99)	30.3	15.7	5.3	41.5
April	29.20 (5.48)	27.20 (5.30)	23.60 (4.85)	4.75	2,106.90 (45.62)	23.0	12.0	77	51.0
May	37.40 (6.18)	33.40 (5.85)	35.00 (5.99)	6.40	3,175.31 (55.90)	27.0	15.0	57	45.1
June	43.40 (6.65)	46.20 (6.85)	42.00 (6.53)	6.05	2,235.53 (47.26)	30.0	18.0	127	50.0
C.D.	0.40	0.51	0.57	0.73	14.67				

*Figures are square root transformed values

** Months of migration period of colonies to Rajasthan

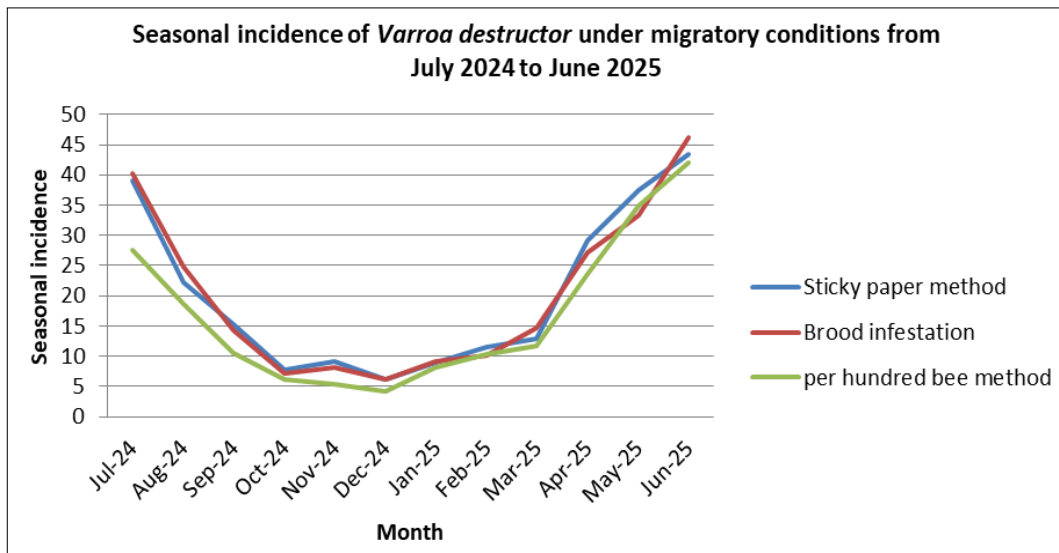


Fig 5: Seasonal incidence of *Varroa destructor* under migratory conditions from July 2024 to June 2025

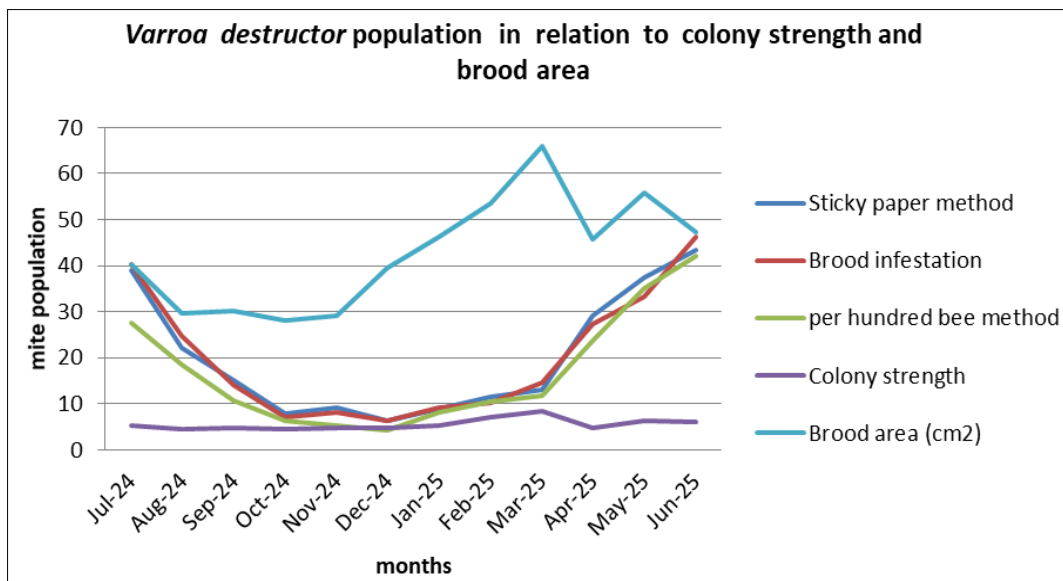


Fig 6: *Varroa destructor* population in relation to colony strength and brood area

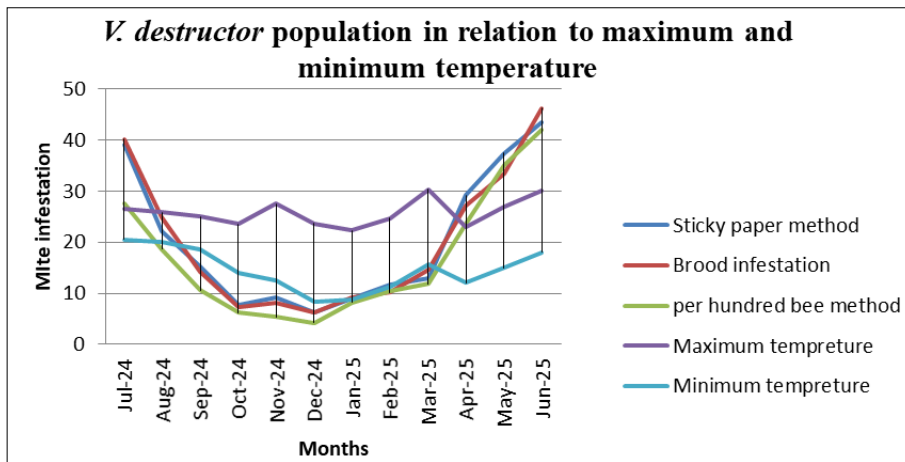


Fig 7: *V. destructor* population in relation to maximum and minimum temperature

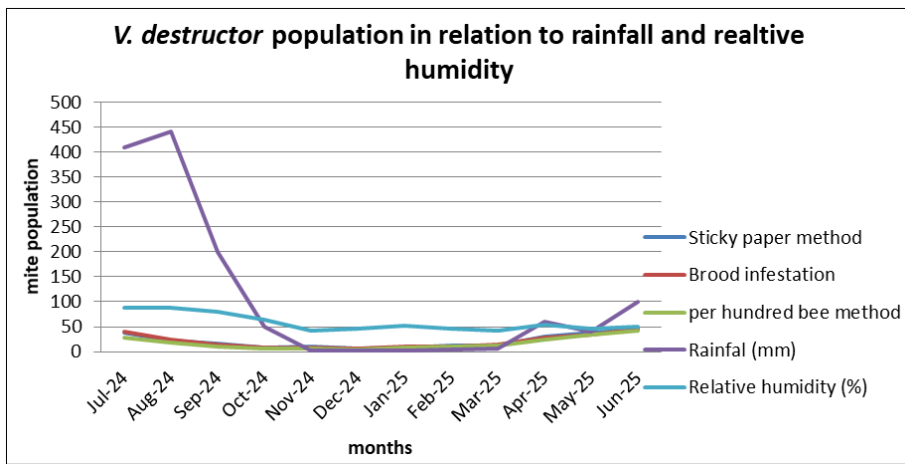


Fig 8: *V. destructor* population in relation to rainfall and relative humidity

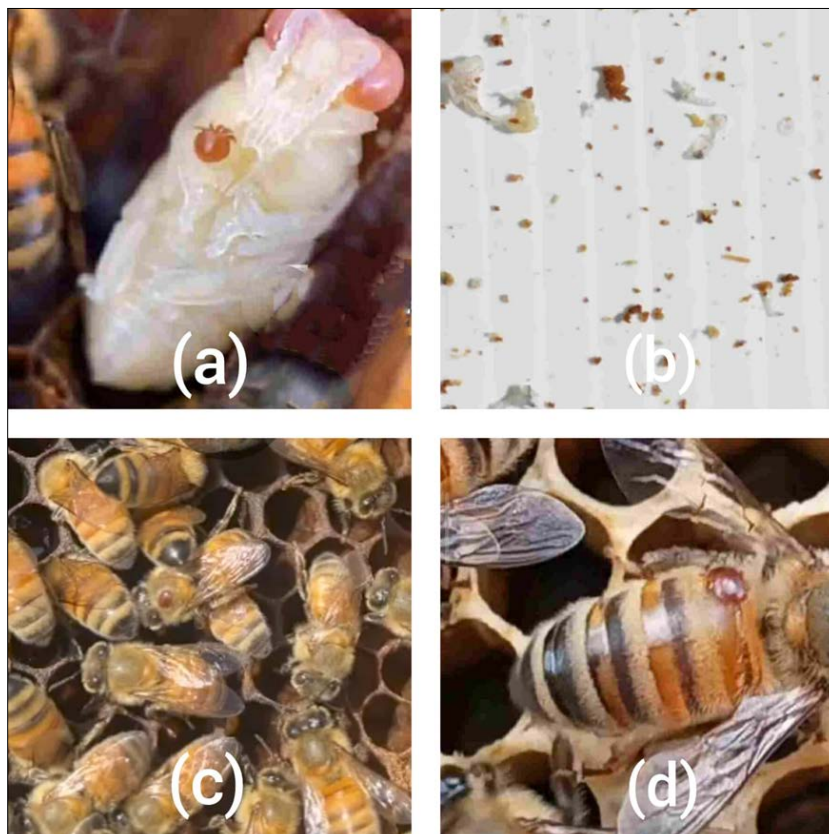


Fig 9: (a) mite infestation on brood (b) mite fall on sticky paper (c) and (d) mite infestation on honey bee

Table 4: Pearson correlation coefficient (r) between incidence of *Varroa destructor* with colony and weather parameters under migratory conditions

Parameters \ Methods	Sticky paper method	Brood infestation	Per hundred bee method
Max. temperature	-0.518	-0.522	-0.522
Min. temperature	0.336	0.340	0.425
Rainfall	0.330	0.353	0.046
Relative humidity	0.047	0.072	-0.171
Colony strength	0.887**	0.886**	0.887**
Brood area	-0.601	-0.603	-0.610

(** significant at 5%)

The present study also evaluated the efficacy of various plant essential oils—thyme, cinnamon, rosemary, peppermint, tea tree, and clove bud against *Varroa destructor* infestation in *Apis mellifera* colonies. Treatments were applied thrice at 7-day intervals, and observations were recorded on brood infestation, mite drop, and brood area development. Initial brood infestation ranged from 38.33% to 48.00%. Seven days after the first treatment, thyme oil showed the most significant reduction in infestation (32.33%), followed by rosemary (34.33%) and peppermint (35.33%). After the third treatment, thyme oil reduced infestation to just 5.66%, reflecting a 92.45% reduction, followed by cinnamon (16.33%; 80.04%) and peppermint (18.66%; 74.34%).

Tea tree oil demonstrated the least effectiveness with only a 51.39% reduction (final infestation: 37.00%). In untreated colonies, infestation rose to 65.33%, underscoring the progressive nature of *V. destructor* without intervention. These findings support previous studies highlighting thymol's acaricidal properties (Calderone and Spivak, 1995; Imdorf *et al.*, 1999) [5, 17], while cinnamaldehyde in cinnamon oil is similarly effective (Abou-Shaara, 2014) [1]. The moderate performance of peppermint and rosemary oils aligns with earlier reports of their disruptive but less persistent effects on mite respiration (Ebrahimi *et al.*, 2014) [12]. Clove oil and tea tree oil were comparatively less effective, consistent with observations by Sammataro *et al.* (1998) [24].

Table 5: Effectiveness of plant essential oils against *V. destructor* infestation in *A. mellifera* colonies applied at an interval of seven days

Treatment	Dose	Brood infestation (%)			
		Initial infestation	7 DAFT*	7 DAST**	7 DATT***
Thyme oil (<i>Thymus vulgaris</i>)	5 ml	44.00 (6.70)	32.33 (5.77)	17.33 (4.27)	5.66 (2.57)
Cinnamon oil (<i>Cinnamomum verum</i>)	5 ml	48.00 (6.97)	38.33 (6.23)	25.33 (5.12)	16.33 (4.15)
Rosemary oil (<i>Rosmarinus officinalis</i>)	5 ml	39.66 (6.37)	34.33 (5.91)	27.33 (5.32)	22.00 (4.79)
Tea tree oil (<i>Melaleuca alternifolia</i>)	5 ml	44.66 (6.75)	43.66 (6.68)	39.33 (6.34)	37.00 (6.16)
Peppermint oil (<i>Mentha piperita</i>)	5 ml	42.66 (6.59)	35.33 (6.00)	26.00 (5.19)	18.66 (4.42)
Clove bud oil (<i>Syzygium aromaticum</i>)	5 ml	46.33 (6.87)	41.00 (6.48)	34.00 (5.91)	28.33 (5.41)
Untreated mite check	—	38.33 (6.25)	51.00 (7.20)	59.00 (7.74)	65.33 (8.14)
C.D.		N/A	10.83 (0.86)	4.18 (0.38)	3.47 (0.37)

#Figures in parentheses are square root (x+1) transformed values

*Days after first treatment, **Days after second treatment and ***Days after third treatment

Table 6: Per cent reduction in *V. destructor* infestation per hundred brood cells

Treatment	Dose	Per cent reduction in infected larvae/100 brood cells		
		7 DAFT*	7 DAST**	7 DATT***
Thyme oil (<i>Thymus vulgaris</i>)	5 ml	44.78%	74.41%	92.45%
Cinnamon oil (<i>Cinnamomum verum</i>)	5 ml	39.98%	65.72%	80.04%
Rosemary oil (<i>Rosmarinus officinalis</i>)	5 ml	34.94%	55.23%	67.45%
Tea tree oil (<i>Melaleuca alternifolia</i>)	5ml	26.53%	42.79%	51.39%
Peppermint oil (<i>Mentha piperita</i>)	5 ml	37.18%	60.41%	74.34%
Clove bud oil (<i>Syzygium aromaticum</i>)	5 ml	33.49%	52.32%	64.12%

*Days after first treatment, **Days after second treatment and ***Days after third treatment

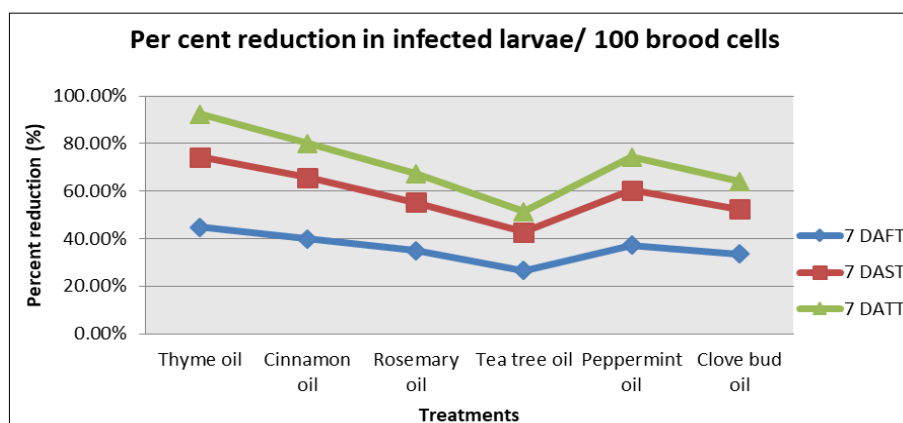


Fig 10: Per cent reduction in infected larvae/ 100 brood cells

The average number of dead or fallen mites post-treatment further confirmed the acaricidal action. Thyme oil caused the highest mite drop (41.66 mites/colony after first treatment), followed by

cinnamon (38.33) and peppermint (34.33). Tea tree oil and clove oil recorded lower mite fall counts (20.66 and 25.66, respectively), while untreated colonies showed the least (7.00 mites/colony).

Table 7: Dead and fallen mite per colony on sticky paper

Treatment	Dose	Average number of dead/ fallen mite/colony			
		Pre count	7 DAFT	7 DAST	7 DATT
Thyme oil (<i>Thymus vulgaris</i>)	5 ml	11.33	41.66 (6.53)*	38.00 (6.24)	34.00 (5.91)
Cinnamon oil (<i>Cinnamomum verum</i>)	5 ml	12.66	38.33 (6.27)	33.33 (5.85)	28.66 (5.44)
Rosemary oil (<i>Rosmarinus officinalis</i>)	5 ml	9.66	30.66 (5.62)	27.00 (5.29)	20.66 (4.65)
Tea tree oil (<i>Melaleuca alternifolia</i>)	5 ml	13.66	20.66 (4.65)	18.00 (4.35)	13.33 (3.78)
Peppermint oil (<i>Mentha piperita</i>)	5 ml	14.66	34.33 (5.94)	30.00 (5.56)	23.66 (4.96)
Clove bud oil (<i>Syzygium aromaticum</i>)	5 ml	12.00	25.66 (5.15)	21.66 (4.75)	17.00 (4.24)
Untreated mite check	–	13.00	7.00 (2.81)	8.66 (3.10)	10.66 (3.41)
C.D.		0.81	3.13 (0.36)	2.08 (0.21)	2.77 (0.29)

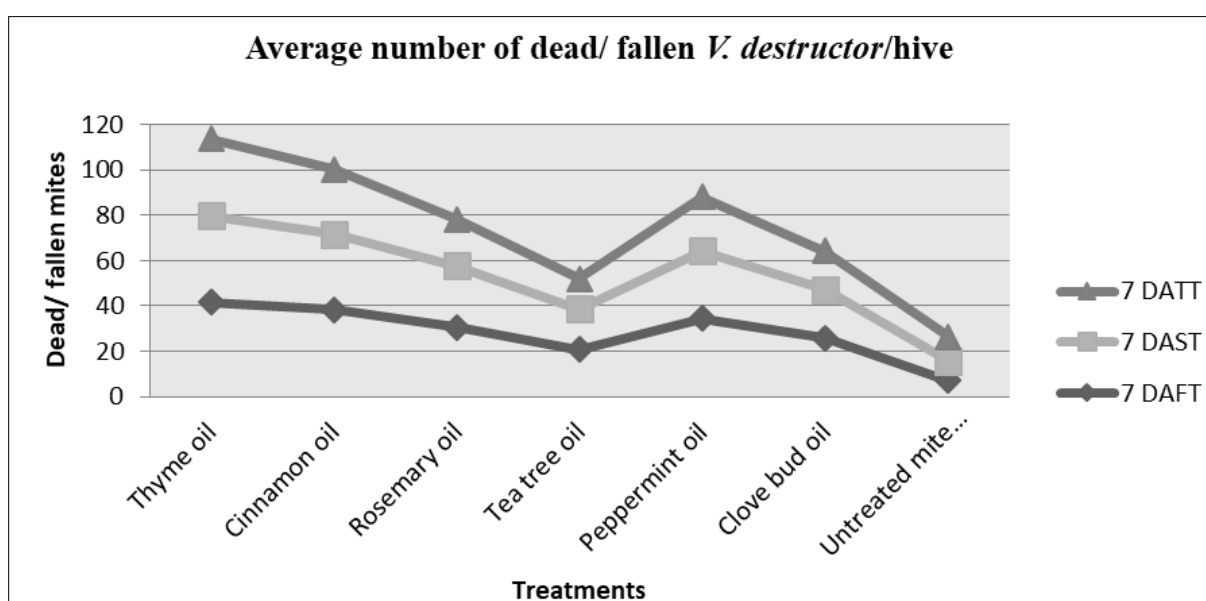


Fig 11: Average number of dead/ fallen *V. destructor*/ hive

Brood area increased significantly in treated colonies compared to untreated ones. Thirty days post-treatment, maximum brood area was observed in colonies treated with thyme oil (3,383.85 cm²), followed by cinnamon (2,757.56 cm²) and peppermint (2,712.89 cm²). Untreated colonies

showed the lowest brood area (1,382.78 cm²), indicating suppressed colony development under high mite load. The results imply that thyme and cinnamon oils not only reduce infestation but also enhance brood development, likely due to improved colony health post-treatment.

Table 8: Cumulative effect of three treatments of plant essential oils applied at 7 days interval on brood area against *V. destructor* infestation in *A. mellifera* colonies

Treatment	Dose	Brood area (cm ²) after three treatment of plant essential oils		
		1 DATT*	15 DATT	30 DATT
Thyme oil (<i>Thymus vulgaris</i>)	5 ml	2,247.14 (47.39)#	2,456.72 (49.56)	3,383.85 (58.17)
Cinnamon oil (<i>Cinnamomum verum</i>)	5 ml	2,306.40 (48.01)	2,357.28 (48.53)	2,757.56 (52.50)
Rosemary oil (<i>Rosmarinus officinalis</i>)	5 ml	2,149.24 (46.35)	2,191.56 (46.80)	2,360.84 (48.58)
Tea tree oil (<i>Melaleuca alternifolia</i>)	5ml	1,966.37 (44.15)	1,936.65 (43.81)	2,005.13 (44.61)
Peppermint oil (<i>Mentha piperita</i>)	5 ml	2,157.94 (46.45)	2,232.91 (47.13)	2,712.89 (51.98)
Clove bud oil (<i>Syzygium aromaticum</i>)	5 ml	1,551.30 (39.14)	1,614.90 (39.96)	2,281.06 (47.72)
Untreated mite check	–	1,893.52 (43.39)	1,791.28 (42.18)	1,382.78 (37.00)
C.D.	–	414.37 (4.95)	550.25 (6.30)	551.99 (6.04)

#Figures in parentheses are square root (x+1) transformed values

*Days after third treatment

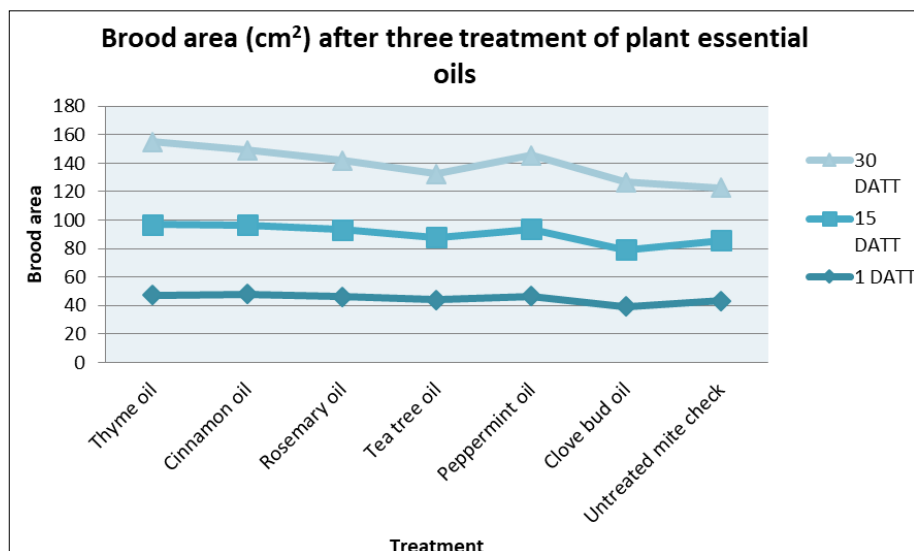


Fig 12: Brood area (cm²) after three treatment of plant essential oils

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Author Contribution

Dr. Sapna Devi (major advisor) analysed the data and manuscript interpretation and analysis. She read and modified manuscript paper writing in the whole process. I read and approved the final manuscript.

Conflict of Interest

No conflict of interest.

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