



STUDIES ON BEHAVIOR OF STINGLESS BEES TO EXTREME CLIMATIC CONDITIONS OF JODHPUR, RAJASTHAN, INDIA

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ABSTRACT

Tetragonula iridipennis represents important pollinators throughout the tropical and subtropical areas including the arid zones of Rajasthan in India. The arid environmental conditions of Jodhpur create demanding conditions because of its high temperatures which combine with scarce rainfall. The article evaluates *T. iridipennis* adaptations to difficult conditions through research on foraging actions alongside nesting strategies together with colony survival responses. The understanding of such adaptation strategies remains fundamental to create conservation plans while protecting their pollination capabilities in arid regions.

1.INTRODUCTION

Many tropical and subtropical ecosystems rely heavily on pollination from stingless bees (tribe Meliponini) as per Vit *et al.* (2013). The Indian species *Tetragonula iridipennis* represents a widespread taxon which enhances pollen transfer functions for numerous crops as well as natural plants across India (Meena *et al.*, 2021). Jodhpur's arid region in Rajasthan faces severe climatic situations where the temperatures surpass 45°C annually and rainfall amounts to about 32 cm throughout the year. Stingless bees in this area must face severe difficulties to sustain their survival and maintain operational efficiency (Roubik, 2006).

The tropical and subtropical ecosystems possess the stingless bees from the Meliponini tribe as their most significant pollinators according to Rasmussen and Camargo (2010) who note their ecological importance for biodiversity and agricultural output. These pollinators bring essential value to the environment because they work efficiently with many different plants (Michener, 2007). *Tetragonula iridipennis*, a dominant stingless bee species in India, plays a vital role in crop pollination, particularly in dryland agriculture systems (Singh & Kumarnag, 2023).

Jodhpur being situated in Rajasthan faces an extreme desert climate because summer temperatures rise beyond 45°C while annual rainfall sticks near 32 cm (IMD, 2020). Stingless bees encounter substantial physiological and behavioral hurdles from their environment because they must overcome hurdles with their foraging abilities as well as preferences for nest sites and requirements for colony survival (Hrncir & Maia-Silva, 2019). The necessary knowledge about *T. iridipennis* adaptation to these climate conditions supports arid ecosystem conservation together with sustainable pollination management practices.

Stingless bees exhibit a high sensitivity to climate changes especially temperature and humidity fluctuations that impact directly their foraging activity and thermoregulation as well as their colony dynamic patterns according to Quezada-Euán *et al.* (2018). Foraging activity along with resource allocation stands as a fundamental life-or-death requirement for colony survival in arid regions with unpredictable floral resources availability (Freitas *et al.*, 2023). Sound arid environmental conditions elevate the risk of stingless bees to encountering habitat loss together with pesticide exposure and pollinator competition (Brown & Paxton, 2009).

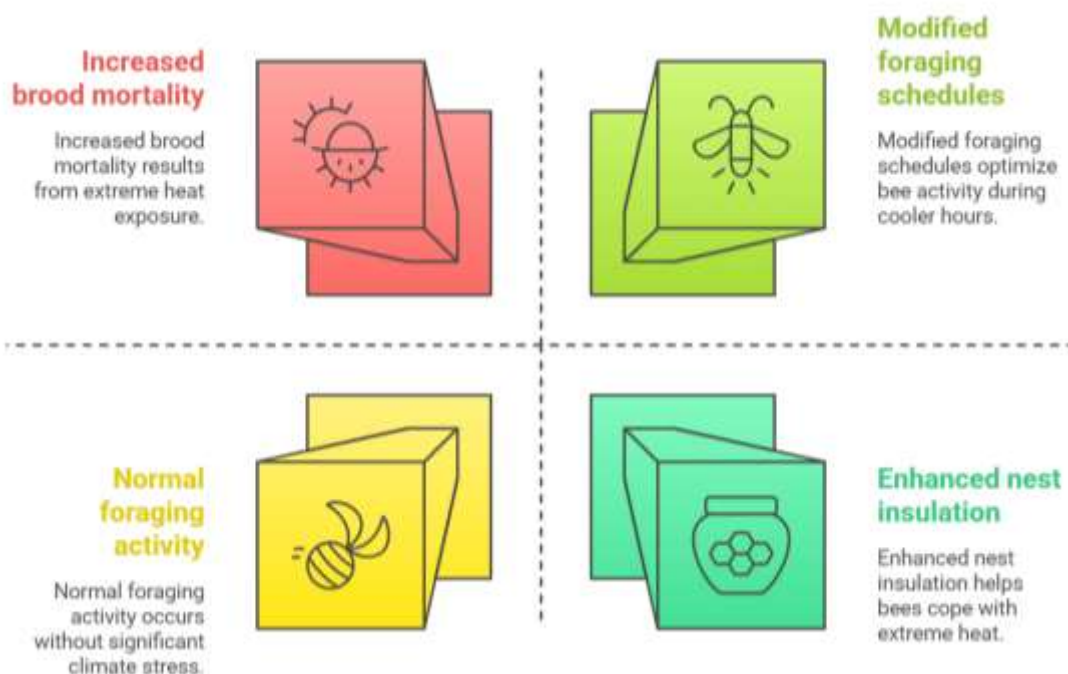
The assessments of how stingless bees behave under extreme conditions represent a pressing need during current climate change because they occur in Jodhpur desert environments. *T. iridipennis*' foraging patterns together with its nesting mechanisms and colony survivability receive examination in response to severe climatic events to develop survival strategies for their continued presence in the region.

2. IMPACT OF EXTREME CLIMATE ON STINGLESS BEES

2.1 FORAGING BEHAVIOUR UNDER HIGH TEMPERATURE

Stingless bees exhibit their foraging behaviors strongly based on surrounding temperature levels according to Hrncir & Maia-Silva (2019). Research indicates that when temperatures increase the number of foraging activities reduces because bees aim to prevent overheating. Stingless bees in Jodhpur exhibit the same behavioral response by foraging during lower temperature times because they need to prevent heat stress (Freitas *et al.*, 2023).

Aspects of bee behavior that are impacted by climate change include changes in nest construction, increased water collection, modified foraging patterns, and changes in the usage of resin for thermal insulation. These crucial behavioral adaptations are depicted in Figure [A], which offers a thorough summary of how stingless bees react to heat stress and preserve ecological processes while assuring colony survival. In order to maintain stingless bee populations in the face of future climate difficulties, more study and conservation efforts are required, as this graphic illustrates the crucial connection between climate change and adaptive methods in these insects.



2.2 NESTING STRATEGIES AND THERMOREGULATION

Stingless bees need appropriate nesting choices to survive in harsh climates according to Roubik (2006). The bees of the *T. iridipennis* species choose their nesting places in regions of shade such as holes in trees and cracks in mud structures as this shields them from heat (Wille & Michener, 1973). Wild bees exhibit inherent behavior to select optimal resting sites because it ensures proper temperatures for developing brood and colony well-being (Vit *et al.*, 2013).

2.3 COLONY HEALTH AND REPRODUCTIVE SUCCESS

The extreme conditions in the environment can generate harmful impacts on colony well-being as well as reproductive outcomes (Hrncir & Maia-Silva, 2019). Floral resources become scarce when temperature rises high and dry periods become extended which weakens colonies and affects their nutritional intake (Freitas *et al.*, 2023). The vulnerability to diseases and pests gets increased by heat stress which makes colonies more prone to failure.

Understanding the behavioral reactions of stingless bees (*Trigona iridipennis*) to environmental stressors is crucial to comprehending how they adjust to the harsh climate in the Jodhpur area. Their foraging activity, nest maintenance, and colony health are greatly influenced by the interaction of temperature variations, humidity levels, and resource availability. Field research findings show that high ambient temperatures above 45°C cause a significant reduction in foraging activity, especially during the hottest parts of the day, which forces bees to move their activity to cooler times (Sabatina *et al.*, 2025). Similarly, an increase in water-foraging trips has been observed under low humidity circumstances (<20%) demonstrating the importance of water collection in nest thermoregulation Souza-Junior *et al.*,(2020). Furthermore, extended exposure to intense heatwaves—more than five days in a row—has been associated with short-term decreases in brood production and changes in queen activity, which may have an effect on colony growth (Madan, 2022).

These issues are made worse by urbanization, as colonies in urban areas have higher mortality rates and stress behaviors than those in rural areas, underscoring the impact of the urban heat island effect (NRDC, 2023). Additionally, stingless bees are increasingly depending on drought-resistant floral resources as a result of seasonal droughts, which might cause nutritional imbalances (Bharath *et al.*, 2019). Table 1 summarizes these adaptive mechanisms and compares important environmental elements and how they affect the behavior of stingless bees. It is essential to comprehend these reactions in order to create conservation plans and sustainable apiculture methods that lessen the threats that climate change poses to pollinator populations.

TABLE:1- BEHAVIORAL ADAPTATIONS OF STINGLESS BEES UNDER EXTREME CLIMATIC CONDITIONS

ENVIRONMENTAL FACTOR	OBSERVED BEE BEHAVIOR	IMPACT ON COLONY	REFERENCES
High Ambient Temperature (>45°C)	Reduced foraging activity during peak heat; increased activity during cooler periods of the day	Limits resource collection; affects colony sustenance	Sabatina <i>et al.</i> , (2025)
Low Humidity (<20%)	Increased water-foraging trips; utilization of water sources for nest cooling	Essential for thermoregulation within nests	Souza-Junior <i>et al.</i> ,(2020)
Intense Solar Radiation	Preference for shaded foraging areas; avoidance of direct sunlight exposure	Protects against heat stress and desiccation	Hrncir <i>et al.</i> ,(2019)
Extreme Heatwaves (Prolonged >5 Days)	Temporary reduction in brood production and queen activity; increased nest insulation behaviors	Affects colony expansion and survival	Madan (2022)
Urban Heat Island Effect	Higher mortality in urban locations compared to rural areas; increased stress behaviors	Urban colonies more vulnerable to extreme conditions	NRDC (2023)
Seasonal Drought Conditions	Increased reliance on drought-resistant floral resources; altered foraging patterns	Changes in diet composition; potential nutritional stress	Bharath <i>et al.</i> (2019)

3. CONSERVATION AND MITIGATION STRATEGIES

To support stingless bees populations in arid regions like jodhpur, several conservation strategies can be implemented:

Habitat restoration:The implementation of drought-tolerant native plants as forage sources creates constant nutrition access to bees which strengthens both their nutritional health and their survival capabilities (Meena *et al.*, 2021).

Artificial nesting sites:The installation of insulated artificial nesting boxes prevents bees from environmental dangers by protecting them from harsh weather conditions and lost habitats (Wille & Michener, 1973).

Research and monitoring:The behavioral ecology research of *T. iridipennis* in arid environments should be studied extensively to direct conservation efforts and adaptive resource management (Hrncir & Maia-Silva, 2019).

CONCLUSION

Tetragonula iridipennis together with other stingless bee species demonstrates specific behavioral adaptations which help them thrive in harsh environmental conditions (Vit *et al.*, 2013). Climate change continues to become more severe which now threatens the survival of these bees. All three environmental stressors such as temperature rise and extended dry periods and diminished habitat availability have made the stingless bee population's future existence precarious. Habitat conservation measures that improve habitat condition and establish protective nesting solutions and guarantee steady floral supplies should serve as a foundation to safeguard these important pollinators throughout Jodhpur's arid Rajasthan territory (Roubik, 2006). More studies should examine the thermoregulatory responses of these insects together with their foraging abilities and their genomic capability for heat tolerance to create successful conservation strategies. The protection of these important ecologically significant pollinators together with the maintenance of their ecosystem functions requires researcher and policymaker and local community partnerships.

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