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Morphometry of stingless bee *Tetragonula iridipennis* smith in Jaipur, Rajasthan

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Abstract

This study presents a morphometric analysis of *Tetragonula iridipennis*, collected from the University of Rajasthan, Jaipur and Rajasthan, India. A total of 30 worker bees were analyzed, measuring 23 morphometric traits using a digital Magnus microscope. The key morphometric traits and their respective mean values ($\pm$ S.D.) include: body length (3.93 ± 0.14 mm), head length (1.48 ± 0.02 mm), head breadth (1.69 ± 0.07 mm), antennal length (1.91 ± 0.05 mm), tongue length (0.81 ± 0.19 mm), thorax length (1.53 ± 0.04 mm), thorax breadth (1.66 ± 0.03 mm), forewing length (3.71 ± 0.09 mm), forewing breadth (1.31 ± 0.11 mm), hind wing length (2.63 ± 0.03 mm), hind wing breadth (0.66 ± 0.03 mm), extent of hamuli (0.17 ± 0.01 mm), and abdomen length (1.82 ± 0.21 mm). Hind leg measurements include: coxa length (0.52 ± 0.02 mm), coxa breadth (0.40 ± 0.01 mm), femur length (1.04 ± 0.03 mm), femur breadth (0.23 ± 0.01 mm), tibia length (1.46 ± 0.03 mm), tibia breadth (0.46 ± 0.05 mm), basitarsus length (0.54 ± 0.02 mm), and basitarsus breadth (0.24 ± 0.03 mm). The detailed morphometric data provide insights into the species' anatomical stability and ecological adaptations, contributing valuable information for future stingless bee biodiversity and conservation research.

Keywords: Hymenoptera, nesting biology, pollination, stingless bee, worker bees

Introduction

Stingless bees are the largest and the most diverse group among the corbiculate eusocial bees. Stingless bees lack a venom apparatus and therefore are incapable of stinging. However, they possess highly developed mandibles, which they use to bite in defense when their colony is threatened by intruders (Singh and Khan, 2019) ^[10]. *Tetragonula iridipennis*, also known as the Indian stingless bee, is classified in the Tribe Meliponini, Family Apidae, and Superfamily Apoidea, within the Order Hymenoptera (Taye, 2020) ^[12]. Stingless bees, like honey bees, are eusocial insects that live in colonies and construct their nests in a variety of cavities, including tree trunks, hollow logs, and brick walls. Additionally, they can be found in a range of other locations such as old walls, ground nests, culvert crevices, termite mounds, orchid roots, and even empty tanks and boxes (Charan *et al.*, 2023; Saaivignesh and Manickavasagam, 2023) ^[2, 9]. These bees are sometimes referred to as "dammer bees" because they collect a resinous substance, which is mixed with wax secreted from their bodies to produce a material known as "cerumen". This cerumen is essential for constructing their nests (Singh and Khan, 2019) ^[10]. Extensive research has been conducted on the morphometric characteristics of *T. iridipennis* worldwide, as evidenced by the studies of Kuberappa *et al.* (2005), Patnaik and Prasad (2007), Danaraddi *et al.* (2012), Rasmussen (2013), Patel and Pastagia (2016), Tej *et al.* (2017), Makkar *et al.* (2018), Singh and Khan (2019), Trianto and Purwanto (2020), Sharma *et al.* (2023) ^[2] and Balaji *et al.* (2023) ^[4, 7, 3, 8, 6, 13, 5, 10, 14, 1]. Despite this extensive body of research, there is a notable absence of detailed morphometric data for *T. iridipennis* from Rajasthan. This lack of regional data hinders a comprehensive understanding of the species morphological variation and adaptation in different ecological settings.

To address this gap, the present study aims to provide a detailed morphometric analysis of *Tetragonula iridipennis* populations from Jaipur, Rajasthan. By examining 23 distinct morphometric traits in worker bees, this study seeks to contribute to the broader understanding of morphological diversity within this species.

The findings from this research will enhance knowledge of the species' adaptation to regional environmental conditions and provide a foundation for future studies on the ecological and evolutionary significance of morphometric variation in stingless bees. Furthermore, the data generated will have implications for conservation strategies to protect pollinator diversity and ensure the stability of ecosystems that depend on these essential pollinators.

Materials and Methods

The morphometric analysis of worker bees from the stingless bee species *T. iridipennis* was conducted at the University of Rajasthan in Jaipur, located at coordinates 26°53'07"N 75°49'12"E. To perform this study, thirty worker bees were meticulously collected from their hive entrances. The bees were initially killed using acetone to ensure the full extension of their external body parts, and then preserved in 70% alcohol to maintain their structural integrity. The dissection and morphometric analysis of the samples were carried out in the Bee Biodiversity Laboratory, Department of Zoology, at the University of Rajasthan. The morphological attributes of each worker bee were recorded following the guidelines set out by Rasmussen (2013) [8]. Measurements of twenty-three distinct morphometric characters were taken using a digital Magnus microscope equipped with specialized measurement software. The specific metrics recorded included body length, head length, antennal length, tongue length, thorax length, thorax breadth, forewing length, forewing breadth, hind wing length, hind wing breadth, extent of hamuli, number of hooks, abdomen length, abdomen breadth, coxa length, coxa breadth, femur length, femur breadth, tibia length, tibia breadth, basitarsus length, and basitarsus breadth (Figure 1-7).

All measurements were taken in duplicate with an accuracy of 0.01 mm. The data was analyzed using Statistical Package for the Social Sciences (SPSS) software, version 22, to calculate the means and standard deviations for each of the morphometric characters.



Fig 1: Worker Bee of *T. iridipennis*

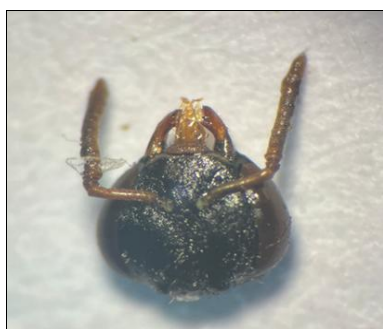


Fig 2: Head with Antenna and Tongue

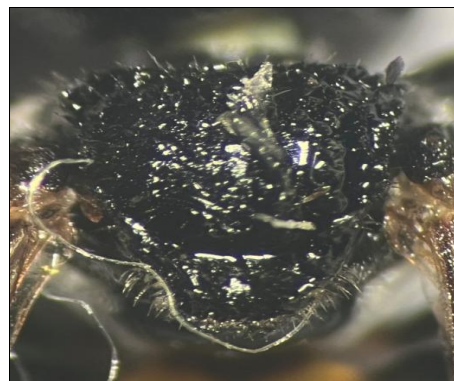


Fig 3: Thorax



Fig 4: Forewing



Fig 5: Hindwing and Hamuli



Fig 6: Abdomen



Fig 7: Hindleg

Results and Discussion

The morphometric analysis of *T. iridipennis* provides detailed insights into its anatomical features, as outlined in Table 1.

Table 1: Morphometric measurements (in millimeters) of different parameters studied in *T. iridipennis*

S. No.	Body parts	Range		
		Minimum (mm)	Maximum (mm)	Mean $\pm$ S.D, (mm)
1	Body length	3.81	4.19	3.93 $\pm$ 0.14
2	Head length	1.45	1.53	1.48 $\pm$ 0.02
3	Head breadth	1.58	1.79	1.69 $\pm$ 0.07
4	Antennal length	1.85	1.97	1.91 $\pm$ 0.05
5	Tongue length	0.62	1.08	0.81 $\pm$ 0.19
6	Thorax length	1.45	1.58	1.53 $\pm$ 0.04
7	Thorax breadth	1.61	1.70	1.66 $\pm$ 0.03
8	Forewing length	3.56	3.83	3.71 $\pm$ 0.09
9	Forewing breadth	1.05	1.39	1.31 $\pm$ 0.11
10	Hind wing length	2.61	2.70	2.63 $\pm$ 0.03
11	Hind wing breadth	0.61	0.71	0.66 $\pm$ 0.03
12	Extent of hamuli	0.16	0.19	0.17 $\pm$ 0.01
13	Number of hooks*	5		
14	Abdomen length	1.58	2.18	1.82 $\pm$ 0.21
15	Abdomen breadth	1.22	1.46	1.34 $\pm$ 0.10
Hind leg				
1	Length of Coxa	0.49	0.56	0.52 $\pm$ 0.02
2	breadth of Coxa	0.39	0.42	0.40 $\pm$ 0.01
3	Length of Femur	1.02	1.10	1.04 $\pm$ 0.03
4	breadth of Femur	0.21	0.25	0.23 $\pm$ 0.01
5	Length of Tibia	1.42	1.51	1.46 $\pm$ 0.03
6	breadth of Tibia	0.42	0.56	0.46 $\pm$ 0.05
7	Length of Basitarsus	0.52	0.57	0.54 $\pm$ 0.02
8	breadth of Basitarsus	0.21	0.30	0.24 $\pm$ 0.03

* Character mentioned indicates numbers

Body Length

The body length of this species ranges from 3.81 mm to 4.19 mm, with a mean measurement of 3.93 $\pm$ 0.14 mm. This range is consistent with the findings of Singh and Khan (2019) [10], who reported body lengths of 3.85 $\pm$ 0.124 mm, as well as the data from Danaraddi *et al.*, (2012) [3] which indicated a body length range of 3.93 to 4.12 mm in related stingless bee species. In contrast, Sharma *et al.* (2023) [2] observed a wider range of 4.10 mm to 4.66 mm, while Makkar *et al.* (2018) [5] reported an average of 3.653 $\pm$ 0.016 mm, both of which differ significantly from our measurements.

Head Appendages

In terms of head appendages, the head length of *T. iridipennis* varies from 1.45 mm to 1.53 mm, with a mean of 1.48 $\pm$ 0.02

mm. Head breadth ranges from 1.58 mm to 1.79 mm, averaging 1.69 $\pm$ 0.07 mm. These findings are consistent with measurements reported by Danaraddi *et al.* (2012) [3] who noted a head length of 1.44 mm to 1.55 mm and a head breadth of similar proportions. The antennal length, measuring between 1.85 mm and 1.97 mm (mean: 1.91 $\pm$ 0.05 mm), aligns closely with the findings of Rasmussen (2013) [8], who reported antennal lengths ranging from 1.80 mm to 1.95 mm. Furthermore, tongue length exhibits significant variability, ranging from 0.62 mm to 1.08 mm (mean: 0.81 $\pm$ 0.19 mm). This variability may reflect differences in feeding strategies and ecological niches, as noted by Patel and Pastagia (2016) [6], who documented similar tongue lengths (0.65 mm to 1.10 mm) in their study.

Thoracic Appendages

The thorax measurements of *T. iridipennis* reveal a length that ranges from 1.45 mm to 1.58 mm (mean: 1.53 $\pm$ 0.04 mm) and a breadth from 1.61 mm to 1.70 mm (mean: 1.66 $\pm$ 0.03 mm). These measurements are consistent with those reported by Tej *et al.* (2017) [13], who documented thorax lengths of 1.50 mm to 1.60 mm. Forewing measurements show a length range of 3.56 mm to 3.83 mm (mean: 3.71 $\pm$ 0.09 mm) and a breadth from 1.05 mm to 1.39 mm, (mean: 1.31 $\pm$ 0.11 mm), which aligns with Singh and Khan (2019) [10], who found similar dimensions (length 3.45 mm to 3.70 mm and breadth 1.19 mm to 1.33 mm). Additionally, a study by Danaraddi *et al.* (2012) [3] aligns with our findings, documenting a forewing length range of 3.50 mm to 3.80 mm and a breadth range of 1.10 mm to 1.35 mm. Hindwing measurements show a length range of 2.61 mm to 2.70 mm (mean: 2.63 $\pm$ 0.03 mm) and a breadth range of 0.61 mm to 0.71 mm (mean: 0.66 $\pm$ 0.03 mm). These findings align with those reported by Singh and Khan (2019) [10], who documented hindwing lengths of 2.43 mm to 2.72 mm and breadths of 0.67 mm to 0.73 mm. Additionally, the morphometric studies conducted by Sharma *et al.* (2023) [2] also showed hindwing lengths ranging from 2.46 mm to 2.75 (mean 2.61 $\pm$ 0.08 mm) and breadths from 0.55 mm to 0.65 mm (mean 0.61 $\pm$ 0.03). The observed number of hamuli on Hindwing was 5.00, which aligns with findings from other studies, further substantiating our results. The extent of hamuli ranges from 0.16 mm to 0.19 mm (mean: 0.17 $\pm$ 0.01).

Abdomen Measurements

Abdomen lengths in our study range from 1.58 mm to 2.18 mm (mean: 1.82 $\pm$ 0.21 mm), and breadths range from 1.22 mm to 1.46 mm (mean: 1.34 $\pm$ 0.10 mm). In comparison, Makkar *et al.* (2018) [5] reported abdomen measurements of length 1.478 $\pm$ 0.004 and breadth 1.162 $\pm$ 0.005. Sharma *et al.* (2023) [2] reported abdomen lengths of 1.41 mm to 1.61 mm (mean 1.52 $\pm$ 0.07). Lastly, Danaraddi *et al.* (2012) [3] documented abdomen breadths ranges from 1.27 mm to 1.51 mm.

Hindleg Measurements

Hindleg measurements indicate coxa lengths ranging from 0.49 mm to 0.56 mm (mean: 0.52 $\pm$ 0.02 mm) and breadths from 0.39 mm to 0.42 mm (mean: 0.40 $\pm$ 0.01 mm). In comparison, Singh and Khan (2019) [10] reported coxa lengths of 0.481 mm to 0.580 mm and breadths from 0.351 mm to 0.513 mm. Femur lengths range from 1.02 mm to 1.10 mm (mean: 1.04 $\pm$ 0.03 mm) and breadths from 0.21 mm to 0.25 mm (mean: 0.23 $\pm$ 0.01 mm). In comparison, Singh and Khan (2019) [10] documented femur lengths ranging from 0.90 mm

to 1.22 mm. and breadths of 0.17 mm to 0.30. Similarly, Danaraddi *et al.* (2012) ^[3] reported femur lengths ranging from 0.86 mm to 0.93 mm and breadths of 0.23 mm to 0.26 mm. Tibia lengths range from 1.42 mm to 1.51 mm (mean: 1.46±0.03 mm) and breadths from 0.42 mm to 0.56 mm (mean: 0.46±0.05 mm). In comparison, Singh and Khan (2019) ^[10] documented tibia lengths of 1.35 mm to 1.52 mm and breadths of 0.45 mm to 0.51 mm. Likewise, Danaraddi *et al.* (2012) ^[3] reported tibia lengths of 1.32 mm to 1.39 mm and breadths of 0.47 mm to 0.50 mm. Basitarsus lengths range from 0.52 mm to 0.57 mm (mean: 0.54±0.02 mm) and breadths from 0.21 mm to 0.30 mm (mean: 0.24±0.03 mm). In comparison, Singh and Khan (2019) ^[10] documented basitarsus lengths of 0.46 mm to 0.66 mm.

In summary, our morphometric analysis of *T. iridipennis* from Jaipur reveals both stability in core anatomical traits (e.g., body length, head/thorax proportions) and notable variability in others (e.g., tongue length, abdomen size). These patterns align with broader biogeographical trends observed in stingless bees, where conserved morphology supports niche specialization while plastic traits enable local adaptation.

Overall, the morphometric measurements of *Tetragonula iridipennis* presented in this study align closely with previous research, underscoring the stability of these anatomical traits across various populations. Our findings reveal consistent ranges in body lengths, head appendages, thoracic dimensions, and leg measurements, reinforcing the idea that these characteristics are well-adapted to the species' ecological niche. Variations in morphometric data observed across different studies can be attributed to geographical and ecological factors, as well as methodological differences. For instance, local environmental conditions may shape specific morphological traits, as noted by Sharma *et al.* (2023) ^[2], while discrepancies in research methodologies, highlighted by Singh and Khan (2019) ^[10] can affect the accuracy of measurements. The consistency of these morphometric traits reinforces the notion that *T. iridipennis* possesses a set of anatomical features that are likely well-adapted to its ecological niche. Future research should further investigate the interplay between environmental factors and morphological adaptations in *Tetragonula iridipennis* and other related stingless bee species. Gaining a deeper understanding of these dynamics will enhance our comprehension of their evolutionary pathways and ecological roles, ultimately supporting broader efforts in biodiversity conservation and ecosystem management.

Conclusion

The present study offers a comprehensive morphometric assessment of *Tetragonula iridipennis* populations in Jaipur, Rajasthan, providing valuable baseline data for this understudied region. The findings affirm the anatomical stability of core morphometric traits across populations, such as body length, thorax dimensions, and wing parameters, while highlighting certain variable traits particularly tongue length and abdomen size that may reflect ecological adaptations. This combination of conserved and variable traits aligns with known evolutionary strategies in stingless bees, supporting their resilience and niche specialization across diverse habitats. Comparisons with previous studies across India underscore the importance of morphometric standardization in bee taxonomy and conservation biology. The documented measurements not only enhance our understanding of intra-species diversity but also provide a

critical reference point for future ecological, genetic, and functional studies on *T. iridipennis*. Given the species' significant role in native pollination systems, morphometric profiling at the regional level is essential for informing conservation policies and sustainable pollinator management. Further investigations integrating environmental parameters, molecular analyses, and behavioral data are recommended to unravel the complex interactions between phenotype and habitat. Such interdisciplinary approaches are crucial for protecting these keystone pollinators against mounting anthropogenic and climatic pressures.

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