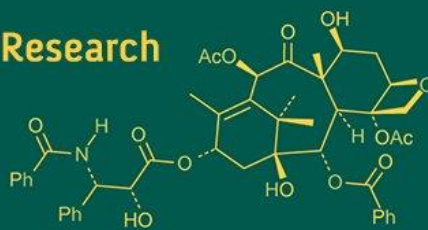


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A new record of *Tetragonula nr. pagdeni* (Schwarz) (Hymenoptera: Apidae: Meliponini) from Ghatikia, Odisha, India, with morphometric assessment of *Tetragonula* spp.

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Abstract

The present study was undertaken to assess morphometric variation among *Tetragonula* populations collected from different locations in Odisha, India, with emphasis on characters useful for population comparison and taxonomic assessment. Seven *Tetragonula* populations, collected from Gadagovindpur, Dhenkanal, Gulehi, Ghatikia, AICRP on Honeybees and Pollinators, Department of Entomology, College of Agriculture Lawn, OUAT, and Udayagiribihar (OUAT Vatika), were examined. Five specimens from each population were measured for morphometric characters of the head, antennae, proboscis, mandibles, wings, legs and body. Considerable variation was observed among the populations for most quantitative characters. The *Tetragonula* population from Ghatikia, identified as *Tetragonula nr. pagdeni* (Schwarz), exhibited comparatively higher values for several head, antennal, wing and leg characters. It recorded the highest forewing length (3.694 mm), forewing width (1.321 mm), hindwing length (2.451 mm) and hindwing width (0.657 mm). The *Tetragonula* population from Dhenkanal also recorded higher values for several characters, including total body length (3.618 mm), fore-leg total length (1.932 mm), middle-leg total length (2.346 mm) and hind-leg total length (6.318 mm). In contrast, the *Tetragonula* population from Gulehi generally exhibited comparatively smaller dimensions for several body and appendage characters, including total body length (3.475 mm) and hind-leg total length (6.266 mm). Hamuli number remained constant at five, while tarsomere number remained constant at four across all populations. The observed morphometric variation provides useful baseline information for population comparison and supports further taxonomic studies of *Tetragonula* in Odisha.

Keywords: Morphometry, stingless bees, *Tetragonula*, *Tetragonula pagdeni*, Odisha, Meliponiculture

1. Introduction

Stingless bees (Hymenoptera: Apidae: Meliponini) are among the oldest eusocial bees and are popularly known as “dammar bees” because they mix a sticky plant resin (dammar) with wax to build and seal their nests. They are distributed throughout the tropical and subtropical regions of Africa, Australasia, the Indo-Malayan realm and parts of the Neotropics (Camargo and Wittmann 1989; Michener 2000) [2, 11]. Like true honey bees (*Apis* spp.), they live in perennial colonies and store honey, but they lack a functional sting possessing only a vestigial stinger and instead defend their nests chiefly by biting.

Their comparatively small body size (2-16 mm) allows stingless bees to exploit floral structures with narrow openings that are inaccessible to larger *Apis* foragers, making them ecologically complementary pollinators of wild and cultivated flora with small or tubular flowers (Devanesan *et al.* 2002; Heard 1999) [4, 7]. This trait, together with their docile nature, ease of colony transfer and modest space requirements, considers the growing global interest in meliponiculture the practice of beekeeping with stingless bees (Wille 1983) [22].

Among the 28 or so species of stingless bees reported from the Indian subcontinent, the majority belong to the genus *Tetragonula* (Rasmussen 2013; Rahman *et al.* 2013) [14, 16], with

Tetragonula iridipennis Smith being the most widely studied species across mainland India. Within this genus, *Tetragonula nr. pagdeni* (Schwarz) is a small-to medium-sized species long recognized from Southeast Asia Thailand, Cambodia, Indonesia and Malaysia where it is valued for its resilience and efficacy in greenhouse crop pollination, including tomato (Wongsa *et al.* 2023) [23]. A population closely resembling *T. pagdeni* was recently documented for the first time in India from the lateritic zone of West Bengal, where marked district-wise morphometric structuring was observed among six districts (Layek *et al.* 2025) [10], hinting that the species may be more widely distributed across eastern India than previously recognized.

Morphometry the quantitative measurement of body parts has proven a robust, cost-effective tool for detecting population-level phenotypic differentiation in stingless bees, often approaching the resolution of molecular methods (Danaraddi 2007; Franco *et al.* 2009; Kishan Tej *et al.* 2017; Singh and Khan 2019; Purwanto and Trianto 2021; Sharma *et al.* 2023; Sabatina *et al.* 2023) [3, 5, 8, 20, 12, 19, 17]. Such data are particularly valuable in regions where genetic reference material is scarce, as they provide a baseline against which taxonomic identity, caste differentiation and geographic variation can be assessed.

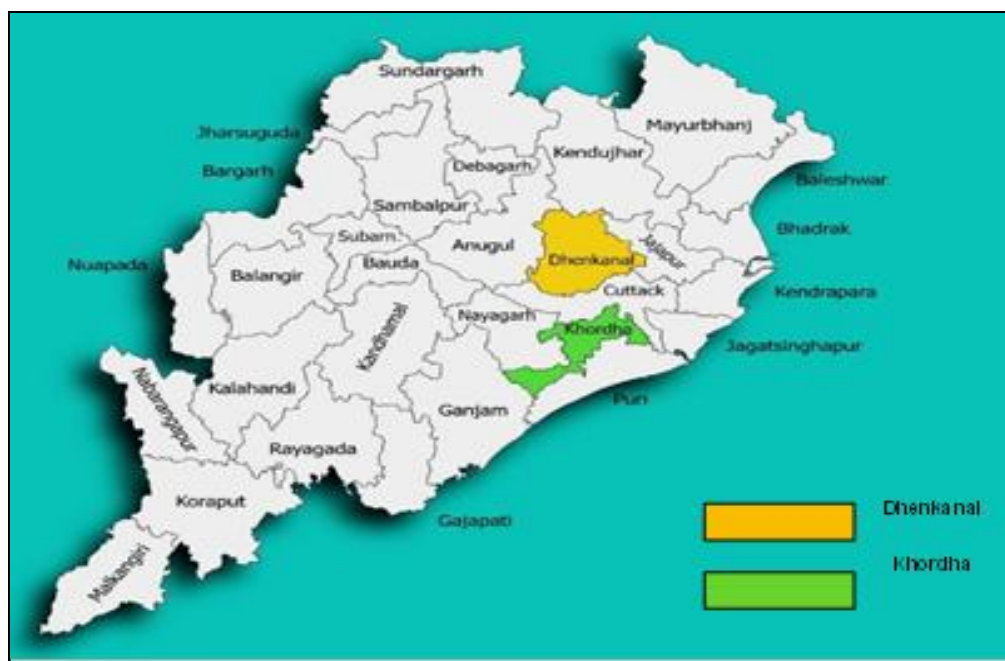
Odisha, with its rich biodiversity and heterogeneous mix of forest, agricultural and urban landscapes, offers favourable conditions for stingless bees, yet the taxonomy and morphometry of its native *Tetragonula* populations have not previously been documented in a systematic, quantitative manner. Khordha and Dhenkanal districts, falling

respectively within the East and South-Eastern Coastal Plain Zone and the Mid-Central Table Land Zone of Odisha, represent two agro-climatically distinct settings well suited to examining fine-scale morphometric variation. The present study was therefore undertaken with the following objectives: (i) collect and taxonomically identify *Tetragonula* spp. populations from seven locations in the Khordha and Dhenkanal districts of Odisha; (ii) quantitatively characterize the head, antennal, wing, leg and body morphometry of the collected workers; and (iii) evaluate the extent and pattern of inter-population morphometric variation across the two districts in relation to their contrasting ecological settings.

2. Materials and Methods

2.1 Study area

The study was carried out under the All India Coordinated Research Project (AICRP) on Honeybees and Pollinators, Department of Entomology, Odisha University of Agriculture and Technology (OUAT), Bhubaneswar, with field sampling conducted in the Khordha and Dhenkanal districts of Odisha during 2024-2025. Sampling spanned two agro-climatic zones: the Mid-Central Table Land Zone, represented by Dhenkanal, Gadagovindpur and Gulehi in Dhenkanal district and the East and South-Eastern Coastal Plain Zone, represented by Ghatikia, the AICRP on Honeybees and Pollinators, Department of Entomology, the College of Agriculture lawn and Udayagiri bihar (OUAT Vatika) in Khordha district. In total, seven locations were sampled (Table 1).



2.2 Specimen collection and identification

Field surveys were carried out in collaboration with local beekeepers to locate natural colonies of stingless bees. Nests were found in various sites, such as tree cavities, wall crevices and underground burrows. The geographic coordinates of each nest were recorded using a handheld GPS device. Adult foraging bees were collected at nest entrances using water-pan traps baited with a honey-and-salt solution, which were placed for 24 h following the method described by Lau and Nieh (2016) [9]. In addition, some

individuals were collected directly from the nest entrances using clean glass vials.

The collected bees were immediately transferred to vials containing 70% ethyl alcohol. Each vial was properly labelled with the locality and date of collection and kept at ambient temperature until transported to the laboratory. The preserved specimens were sent to the Biosystematics Laboratory, Department of Entomology, University of Agricultural Sciences, GKVK, Bengaluru for taxonomic identification. The identification was performed using

standard diagnostic keys and morphological characters described for Indian *Tetragonula* by Rasmussen (2013) ^[16].

2.3 Morphometric assessment

Undamaged, intact worker bees were collected from each location and selected for detailed measurement. The mean of five specimens per location was calculated. The morphometric characters were recorded with a precision of 0.001 mm using a calibrated stereo-zoom binocular microscope equipped with an ocular micrometer. Morphometric characters comprised the length and width of the head; scape length (SL) of antennal segments, pedicel length (PDL), flagellum length (FL), and total antennal length; length of the proboscis; mandible length; width of the forewing and hindwing; number of wing-coupling hamuli; the coxa, trochanter, femur, tibia, and tarsus lengths, tarsomere number, and total length of the foreleg, midleg, and hindleg, each measured separately; and thorax length (THL), abdomen length (ABL), and total body length (BL).

2.4 Statistical analysis

Morphometric data recorded for each body part were suitably transformed following Gomez and Gomez (1984) ^[6] and analyzed adopting a completely randomized design (CRD). For each character, the mean, standard deviation (SD), standard error of the mean (SE(m) $\pm$) and critical difference (CD (P = 0.05) were computed to assess and compare location wise variability and to establish reliable morphometric distinctions among the sampled populations.

3. Results and Discussion

3.1 Occurrence and identification of *Tetragonula* populations

Field surveys conducted across Khordha and Dhenkanal districts of Odisha resulted in the collection of seven *Tetragonula* populations from different habitats. Six populations, collected from Gadagovindpur, Dhenkanal, Gulehi, the AICRP on Honeybees and Pollinators Department of Entomology, the College of Agriculture lawn and Udayagiri bihar (OUAT Vatika), were identified as *Tetragonula* sp. based on external morphological characters. A population collected from Ghatikia was identified as *Tetragonula* nr. *pagdeni* (Schwarz), representing the first record of this taxon from Odisha.

The Ghatikia record is of particular taxonomic and biogeographic interest. *Tetragonula pagdeni* has historically been associated mainly with Southeast Asia, including Thailand, Cambodia, Indonesia and Malaysia (Sakagami 1961; Wongsu et al. 2023) ^[18, 23] and its occurrence in India was reported only recently from the lateritic region of West Bengal (Layek et al. 2025) ^[10]. The present observation therefore extends the known distribution of the *T. pagdeni* complex further south along the eastern Indian region. Since the taxon was detected at only one locality in the present survey, however, the finding should be interpreted as a new state record rather than evidence of widespread distribution in Odisha. The occurrence nevertheless indicates that targeted surveys in similar habitats may reveal additional populations in Odisha and neighbouring areas.

3.2 Morphometric characteristics of head and antennae

Considerable variation was observed in the morphometric characters among the *Tetragonula* populations collected from different locations in Odisha (Table-2). The Ghatikia

population of *Tetragonula* nr. *pagdeni* recorded the highest values for head length (1.219 ± 0.014 mm), head width (1.576 ± 0.007 mm), scape length (0.509 ± 0.008 mm), flagellum length (1.122 ± 0.001 mm), total antennal length (1.746 ± 0.003 mm) and mandible length (0.494 ± 0.015 mm). The Dhenkanal population recorded the highest proboscis length (0.654 ± 0.040 mm). In contrast, the Gulehi population generally exhibited comparatively smaller dimensions, with the lowest head length (1.155 ± 0.013 mm), head width (1.526 ± 0.012 mm), scape length (0.456 ± 0.006 mm) and mandible length (0.340 ± 0.028 mm). Pedicel length showed relatively narrow variation among the populations, ranging from 0.112 ± 0.000 mm at the AICRP location to 0.115 ± 0.008 mm at Dhenkanal. Total antennal length ranged from 1.669 ± 0.019 mm at Gadagovindpur to 1.746 ± 0.003 mm at Ghatikia. Overall, the Ghatikia population showed relatively larger morphometric dimensions, whereas the Gulehi population exhibited comparatively smaller measurements. Such differences are consistent with earlier observations of geographic variation in *Tetragonula* populations. Kishan Tej et al. (2017) ^[8] reported differences in head, wing and leg dimensions among *T. iridipennis* populations from different districts of Tamil Nadu. Similarly, Sabatina et al. (2023) ^[17] demonstrated the usefulness of head width and other morphometric traits in differentiating feral *Tetragonula* populations. The present observations therefore support the value of head and antennal measurements as descriptors of population-level morphological variation, although they should not be considered diagnostic on their own because of potential overlap among closely related taxa.

3.3 Wing morphometry and conserved structural characters

The wing morphometric characters showed relatively narrow variation among the *Tetragonula* populations collected from different locations in Odisha. The Ghatikia population of *Tetragonula* nr. *pagdeni* recorded the highest values for all four wing dimensions, with forewing length of 3.694 ± 0.003 mm, forewing width of 1.321 ± 0.001 mm, hindwing length of 2.451 ± 0.002 mm and hindwing width of 0.657 ± 0.001 mm. The Dhenkanal population also showed comparatively higher wing dimensions, with forewing length of 3.691 ± 0.004 mm, forewing width of 1.320 ± 0.000 mm, hindwing length of 2.450 ± 0.003 mm and hindwing width of 0.654 ± 0.001 mm. The Gulehi population recorded comparatively smaller forewing width (1.313 ± 0.001 mm) and hindwing width (0.643 ± 0.001 mm). The AICRP population recorded the lowest forewing length (3.671 ± 0.003 mm), while Udayagiribihar showed a similar value (3.671 ± 0.002 mm). The number of hamuli remained constant at five in all populations, indicating no variation in this character. Overall, Ghatikia showed the largest wing dimensions, whereas Gulehi generally exhibited comparatively smaller measurements. The results obtained is consistent with earlier descriptions of *Tetragonula/Trigona* (Raakhee and Devanesan 2000; Kishan Tej et al. 2017; Rasmussen 2013) ^[8, 13, 16] and supports the interpretation that hamuli number represents a conserved structural character with limited utility for detecting population-level differentiation.

The forewing width recorded in the present study (1.313 – 1.321 mm) was close to the value of approximately 1.32 mm reported by Rasmussen (2013) ^[16] for *T. iridipennis*.

3.4 Leg morphometric characteristics

The morphometric measurements of the fore, middle and hind legs showed clear variation among the *Tetragonula* populations from different locations in Odisha (Tables 4-6). In the fore leg (Table 4), the Ghatikia population of *Tetragonula nr. pagdeni* recorded the highest coxa (0.242 ± 0.016 mm), trochanter (0.160 ± 0.010 mm), femur (0.454 ± 0.020 mm), tibia (0.376 ± 0.011 mm) and total leg length (1.922 ± 0.013 mm). Dhenkanal recorded the highest tarsus length (0.634 ± 0.020 mm), while the lowest total fore-leg length was observed at the College of Agriculture Lawn, OUAT (1.814 ± 0.018 mm). All populations possessed four tarsomeres.

For the middle leg (Table 5), Dhenkanal recorded the highest coxa (0.278 ± 0.013 mm), trochanter (0.224 ± 0.029 mm), femur (0.566 ± 0.019 mm), tibia (0.646 ± 0.026 mm), tarsus (0.754 ± 0.027 mm) and total leg length (2.346 ± 0.028 mm). Ghatikia showed comparable values, with a total middle-leg length of 2.344 ± 0.024 mm. The lowest total length was recorded at the College of Agriculture Lawn (2.240 ± 0.040 mm). Four tarsomeres were consistently observed in all populations.

The hind leg exhibited the greatest dimensions among the three pairs of legs (Table 6). Ghatikia recorded the highest coxa (1.130 ± 0.033 mm), tarsus (1.600 ± 0.015 mm) and total leg length (6.300 ± 0.031 mm), whereas Dhenkanal had the highest trochanter (0.982 ± 0.008 mm), femur (1.320 ± 0.033 mm) and tibia (1.459 ± 0.002 mm). Gulehi recorded the lowest total hind-leg length (6.266 ± 0.036 mm). Thus, Ghatikia and Dhenkanal generally showed larger leg dimensions, while Gulehi and the College of Agriculture Lawn populations tended to have comparatively smaller measurements. Across all three leg pairs, the tarsomere number remained constant at four.

3.5 Body morphometric variation among *Tetragonula* populations

Variation was observed in body morphometric characters among the *Tetragonula* populations collected from different locations in Odisha (Table 7). The Ghatikia population of *Tetragonula nr. pagdeni* recorded the highest head length (1.219 ± 0.014 mm) and abdomen length (1.437 ± 0.005 mm), whereas Dhenkanal recorded the highest thorax length (1.479 ± 0.007 mm). The highest total body length was also recorded in the Ghatikia population (3.626 ± 0.019 mm), closely followed by Dhenkanal (3.618 ± 0.024 mm). The Gulehi population exhibited the lowest head length (1.155 ± 0.013 mm), thorax length (1.433 ± 0.016 mm), abdomen length (1.361 ± 0.016 mm) and total body length (3.475 ± 0.039 mm). The AICRP population also showed comparatively smaller body dimensions, particularly head length (1.145 ± 0.012 mm). Overall, Ghatikia showed comparatively larger body dimensions, while Gulehi recorded the smallest overall body measurements among the populations studied (Fig. 1).

This geographic pattern is particularly interesting when considered in relation to habitat characteristics. Ghatikia and Dhenkanal represent relatively heterogeneous environments containing combinations of homestead gardens, orchards and agricultural fields, whereas the College of Agriculture lawn and Gulehi were comparatively homogeneous or dominated by built-up and lawn habitats. A similar association between habitat characteristics and body size has been suggested for *T. nr. pagdeni* populations in West

Bengal, where larger-bodied populations were associated with greater floral-resource diversity and more variable microclimatic conditions (Layek *et al.* 2025) ^[10]. Resource availability can influence bee growth and body size through its effects on larval nutrition and colony resource acquisition (Ramalho *et al.* 1998) ^[15]. Therefore, the larger body dimensions observed at Ghatikia and Dhenkanal may partly reflect local ecological conditions. Nevertheless, this interpretation remains tentative because the present study did not directly quantify floral-resource availability, microclimate or colony-level nutritional status.

3.6 Comparison with *Tetragonula nr. pagdeni* from West Bengal

The morphometric characteristics of the Ghatikia population showed considerable similarity with those reported for *Tetragonula nr. pagdeni* populations from West Bengal. Layek *et al.* (2025) ^[10], based on 440 workers from six lateritic districts of West Bengal, reported body length ranging from 3.489 to 3.706 mm, compared with 3.475-3.626 mm in the present Odisha populations. Head width also showed substantial overlap, ranging from 1.521-1.599 mm in West Bengal and 1.521-1.576 mm in Odisha. However, forewing length was comparatively lower in the Odisha populations (3.671-3.694 mm) than in West Bengal (3.708-3.860 mm). The overlap in body length and head width, together with the overall morphological similarity, supports the preliminary identification of the Ghatikia population as *Tetragonula nr. pagdeni*. Nevertheless, differences in wing dimensions highlight the need for caution in species identification based solely on morphometric characters. Molecular analysis and examination of additional colonies would provide stronger confirmation.

3.7 Taxonomic significance and limitations

The present study provides quantitative morphometric information on *Tetragonula* populations sampled from different locations in Odisha and establishes a useful baseline for future taxonomic studies. The observed differences in head, antennal, wing, leg and body dimensions indicate appreciable morphometric variation among populations, whereas structural characters such as five hamuli and four tarsomeres remained constant. However, these data alone cannot distinguish environmental plasticity from genetic differentiation. The relatively small sample size of five workers per population and examination of only the worker caste are additional limitations. Moreover, identification of the Ghatikia population as *Tetragonula nr. pagdeni* was based primarily on morphological characters and lacked molecular corroboration. Previous studies have demonstrated the usefulness of wing morphometry and the integration of morphometric and molecular approaches for characterising and resolving taxonomic variation in stingless bees (Francoy *et al.*, 2009; Urueña *et al.*, 2022) ^[5, 21]. The need for an integrative approach is further highlighted by evidence of cryptic speciation within *Tetragonula* (Ador *et al.*, 2023) ^[1]. Therefore, the present record represents an important addition to the known *Tetragonula* diversity of Odisha, while broader sampling and molecular confirmation are required to establish its taxonomic identity and distribution with greater confidence.

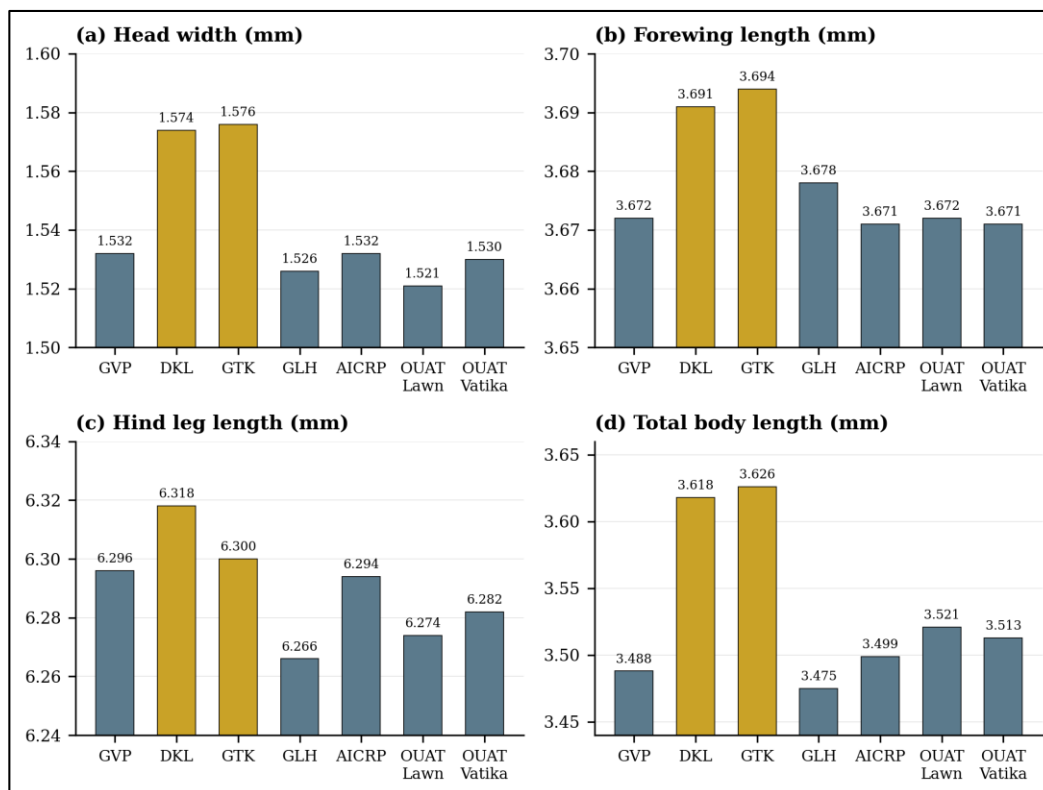


Fig 1: Variation in head width, forewing length, hind-leg length and total body length of *Tetragonula* spp. workers across the seven sampled locations. GVP = Gadagovindpur; DKL = Dhenkanal; GTK = Ghatikia; GLH = Gulehi; AICRP = AICRP on Honeybees and Pollinators, Dept. of Entomology; OUAT Lawn = College of Agriculture Lawn, OUAT; OUAT Vatika = Udayagiribihar (OUAT Vatika).

Table 1: Distribution and identification of *Tetragonula* populations collected from different locations in Odisha, India

Sl. No.	Agro-climatic zone	District	Sampling location	Coordinates	Species identification
1	Mid Central Table Land Zone	Dhenkanal	Gadagovindpur	20.64° N, 85.68° E	<i>Tetragonula</i> sp.
2	Mid Central Table Land Zone	Dhenkanal	Dhenkanal	20.64° N, 85.68° E	<i>Tetragonula</i> sp.
3	Mid Central Table Land Zone	Dhenkanal	Gulehi	20.69° N, 85.30° E	<i>Tetragonula</i> sp.
4	East and South-Eastern Coastal Plain Zone	Khordha	Ghatikia	20.26° N, 85.77° E	<i>Tetragonula</i> nr. <i>pagdeni</i> (Schwarz)
5	East and South-Eastern Coastal Plain Zone	Khordha	AICRP on Honeybees and Pollinators, Dept. of Entomology	20.26° N, 85.81° E	<i>Tetragonula</i> sp.
6	East and South-Eastern Coastal Plain Zone	Khordha	College of Agriculture Lawn, OUAT	20.26° N, 85.81° E	<i>Tetragonula</i> sp.
7	East and South-Eastern Coastal Plain Zone	Khordha	Udayagiribihar (OUAT Vatika)	20.27° N, 85.79° E	<i>Tetragonula</i> sp.

Coordinates are given as decimal-degree latitude and longitude at each nest site

Table 2: Variation in morphometric characters among *Tetragonula* populations collected from different locations in Odisha, India.

<i>Tetragonula</i> population	Sampling location	Head length	Head width	Scape length	Pedicle length	Flagellum length	Total antennal length	Proboscis length	Mandible length
1. <i>Tetragonula</i> sp.	Gadagovindpur	1.168 ± 0.020	1.532 ± 0.010	0.460 ± 0.023	0.112 ± 0.001	1.114 ± 0.002	1.669 ± 0.019	0.578 ± 0.029	0.358 ± 0.040
2. <i>Tetragonula</i> sp.	Dhenkanal	1.204 ± 0.012	1.574 ± 0.009	0.508 ± 0.014	0.115 ± 0.008	1.119 ± 0.004	1.743 ± 0.005	0.654 ± 0.040	0.452 ± 0.024
3. <i>Tetragonula</i> sp.	Gulehi	1.155 ± 0.013	1.526 ± 0.012	0.456 ± 0.006	0.114 ± 0.001	1.116 ± 0.001	1.696 ± 0.009	0.576 ± 0.027	0.340 ± 0.028
4. <i>Tetragonula</i> nr. <i>pagdeni</i> (Schwarz)	Ghatikia	1.219 ± 0.014	1.576 ± 0.007	0.509 ± 0.008	0.114 ± 0.004	1.122 ± 0.001	1.746 ± 0.003	0.636 ± 0.036	0.494 ± 0.015
5. <i>Tetragonula</i> sp.	AICRP on Honeybees and Pollinators, Dept. of Entomology	1.145 ± 0.012	1.532 ± 0.008	0.458 ± 0.007	0.112 ± 0.000	1.118 ± 0.001	1.687 ± 0.006	0.543 ± 0.052	0.376 ± 0.030
6. <i>Tetragonula</i> sp.	College of Agriculture Lawn, OUAT	1.170 ± 0.011	1.521 ± 0.012	0.459 ± 0.017	0.113 ± 0.001	1.118 ± 0.000	1.705 ± 0.006	0.534 ± 0.043	0.334 ± 0.032
7. <i>Tetragonula</i> sp.	Udayagiribihar (OUAT Vatika)	1.157 ± 0.019	1.530 ± 0.011	0.461 ± 0.016	0.114 ± 0.002	1.117 ± 0.000	1.687 ± 0.009	0.566 ± 0.059	0.338 ± 0.061
	SE(m) ±	0.006	0.004	0.006	0.001	0.001	0.004	0.019	0.016
	CD (P = 0.05)	0.01	0.01	0.01	0.00	0.00	0.01	0.05	0.04

Data are presented as Mean ± SD (n = 5 specimens per location); SE (m) ± = standard error of mean; CD (P = 0.05) = critical difference at the 5% level of significance

Table 3: Variation in wing morphometric characters and hamuli number among *Tetragonula* populations collected from different locations in Odisha, India.

<i>Tetragonula</i> population	Sampling location	Forewing length	Forewing width	Hindwing length	Hindwing width	Hamuli No.
1. <i>Tetragonula</i> sp.	Gadagovindpur	3.672 ± 0.012	1.315 ± 0.001	2.441 ± 0.001	0.648 ± 0.002	5
2. <i>Tetragonula</i> sp.	Dhenkanal	3.691 ± 0.004	1.320 ± 0.000	2.450 ± 0.003	0.654 ± 0.001	5
3. <i>Tetragonula</i> sp.	Gulehi	3.678 ± 0.003	1.313 ± 0.001	2.444 ± 0.002	0.643 ± 0.001	5
4. <i>Tetragonula</i> nr. <i>pagdeni</i> (Schwarz)	Ghatikia	3.694 ± 0.003	1.321 ± 0.001	2.451 ± 0.002	0.657 ± 0.001	5
5. <i>Tetragonula</i> sp.	AICRP on Honeybees and Pollinators, Dept. of Entomology	3.671 ± 0.003	1.313 ± 0.001	2.446 ± 0.001	0.649 ± 0.001	5
6. <i>Tetragonula</i> sp.	College of Agriculture Lawn, OUAT	3.672 ± 0.002	1.314 ± 0.000	2.445 ± 0.002	0.644 ± 0.003	5
7. <i>Tetragonula</i> sp.	Udayagiribihar (OUAT Vatika)	3.671 ± 0.002	1.314 ± 0.001	2.446 ± 0.001	0.647 ± 0.002	5
	SE(m) ±	0.002	0.000	0.001	0.001	0.000
	CD (P = 0.05)	0.01	0.01	0.01	0.01	0.000

Data are presented as Mean ± SD (n = 5 specimens per location); SE(m) ± = standard error of mean; CD (P = 0.05) = critical difference at the 5% level of significance.

Table 4: Variation in fore leg morphometric characters among *Tetragonula* populations collected from different locations in Odisha, India.

<i>Tetragonula</i> population	Sampling location	Coxa	Trochanter	Femur	Tibia	Tarsus	Tarsomere No.	Total leg length
1. <i>Tetragonula</i> sp.	Gadagovindpur	0.172 ± 0.016	0.114 ± 0.011	0.368 ± 0.022	0.284 ± 0.015	0.566 ± 0.030	4	1.854 ± 0.027
2. <i>Tetragonula</i> sp.	Dhenkanal	0.224 ± 0.023	0.132 ± 0.026	0.454 ± 0.027	0.366 ± 0.028	0.634 ± 0.020	4	1.932 ± 0.013
3. <i>Tetragonula</i> sp.	Gulehi	0.184 ± 0.013	0.146 ± 0.027	0.360 ± 0.021	0.266 ± 0.018	0.556 ± 0.029	4	1.856 ± 0.019
4. <i>Tetragonula</i> nr. <i>pagdeni</i> (Schwarz)	Ghatikia	0.242 ± 0.016	0.160 ± 0.010	0.454 ± 0.020	0.376 ± 0.011	0.632 ± 0.019	4	1.922 ± 0.013
5. <i>Tetragonula</i> sp.	AICRP on Honeybees and Pollinators, Dept. of Entomology	0.166 ± 0.020	0.110 ± 0.018	0.360 ± 0.024	0.274 ± 0.018	0.588 ± 0.014	4	1.834 ± 0.018
6. <i>Tetragonula</i> sp.	College of Agriculture Lawn, OUAT	0.146 ± 0.036	0.122 ± 0.025	0.350 ± 0.032	0.310 ± 0.024	0.606 ± 0.020	4	1.814 ± 0.018
7. <i>Tetragonula</i> sp.	Udayagiribihar (OUAT Vatika)	0.188 ± 0.019	0.116 ± 0.032	0.376 ± 0.029	0.318 ± 0.025	0.572 ± 0.016	4	1.834 ± 0.015
	SE(m) ±	0.009	0.010	0.011	0.009	0.010	0.000	0.008
	CD (P = 0.05)	0.02	0.02	0.03	0.02	0.02	0.000	0.02

Data are presented as Mean ± SD (n = 5 specimens per location); SE(m) ± = standard error of mean; CD (P = 0.05) = critical difference at the 5% level of significance.

Table 5: Variation in middle-leg morphometric characters among *Tetragonula* populations collected from different locations in Odisha, India.

<i>Tetragonula</i> population	Sampling location	Coxa	Trochanter	Femur	Tibia	Tarsus	Tarsomere No.	Total leg length
1. <i>Tetragonula</i> sp.	Gadagovindpur	0.248 ± 0.014	0.154 ± 0.018	0.520 ± 0.027	0.546 ± 0.025	0.652 ± 0.025	4	2.276 ± 0.020
2. <i>Tetragonula</i> sp.	Dhenkanal	0.278 ± 0.013	0.224 ± 0.029	0.566 ± 0.019	0.646 ± 0.026	0.754 ± 0.027	4	2.346 ± 0.028
3. <i>Tetragonula</i> sp.	Gulehi	0.228 ± 0.017	0.150 ± 0.027	0.504 ± 0.013	0.560 ± 0.020	0.656 ± 0.027	4	2.272 ± 0.021
4. <i>Tetragonula</i> nr. <i>pagdeni</i> (Schwarz)	Ghatikia	0.276 ± 0.011	0.202 ± 0.019	0.562 ± 0.019	0.630 ± 0.033	0.752 ± 0.025	4	2.344 ± 0.024
5. <i>Tetragonula</i> sp.	AICRP on Honeybees and Pollinators, Dept. of Entomology	0.226 ± 0.013	0.148 ± 0.013	0.500 ± 0.015	0.550 ± 0.027	0.648 ± 0.034	4	2.260 ± 0.029
6. <i>Tetragonula</i> sp.	College of Agriculture Lawn, OUAT	0.224 ± 0.024	0.146 ± 0.029	0.512 ± 0.025	0.522 ± 0.044	0.646 ± 0.030	4	2.240 ± 0.040
7. <i>Tetragonula</i> sp.	Udayagiribihar (OUAT Vatika)	0.228 ± 0.028	0.158 ± 0.017	0.498 ± 0.031	0.532 ± 0.030	0.674 ± 0.028	4	2.254 ± 0.028
	SE(m) ±	0.008	0.010	0.010	0.013	0.012	0.000	0.012
	CD (P = 0.05)	0.02	0.02	0.02	0.03	0.03	0.000	0.03

Data are presented as Mean ± SD (n = 5 specimens per location); SE(m) ± = standard error of mean; CD (P = 0.05) = critical difference at the 5% level of significance.

Table 6: Variation in hind-leg morphometric characters among *Tetragonula* populations collected from different locations in Odisha, India.

<i>Tetragonula</i> population	Sampling location	Coxa	Trochanter	Femur	Tibia	Tarsus	Tarsomere No.	Total leg length
1. <i>Tetragonula</i> sp.	Gadagovindpur	1.074 ± 0.030	0.942 ± 0.019	1.298 ± 0.016	1.446 ± 0.001	1.554 ± 0.027	4	6.296 ± 0.028
2. <i>Tetragonula</i> sp.	Dhenkanal	1.126 ± 0.015	0.982 ± 0.008	1.320 ± 0.033	1.459 ± 0.002	1.586 ± 0.018	4	6.318 ± 0.019
3. <i>Tetragonula</i> sp.	Gulehi	1.048 ± 0.021	0.880 ± 0.026	1.278 ± 0.019	1.443 ± 0.002	1.548 ± 0.021	4	6.266 ± 0.036
4. <i>Tetragonula</i> nr. <i>pagdeni</i> (Schwarz)	Ghatikia	1.130 ± 0.033	0.968 ± 0.017	1.279 ± 0.030	1.460 ± 0.002	1.600 ± 0.015	4	6.300 ± 0.031
5. <i>Tetragonula</i> sp.	AICRP on Honeybees and Pollinators, Dept. of Entomology	1.060 ± 0.027	0.852 ± 0.048	1.292 ± 0.022	1.443 ± 0.002	1.554 ± 0.032	4	6.294 ± 0.035
6. <i>Tetragonula</i> sp.	College of Agriculture Lawn, OUAT	1.070 ± 0.033	0.808 ± 0.023	1.272 ± 0.031	1.444 ± 0.002	1.562 ± 0.019	4	6.274 ± 0.020
7. <i>Tetragonula</i> sp.	Udayagiribihar (OUAT Vatika)	1.080 ± 0.027	0.840 ± 0.021	1.286 ± 0.030	1.446 ± 0.001	1.586 ± 0.015	4	6.282 ± 0.026
	SE(m) ±	0.012	0.011	0.012	0.001	0.009	0.000	0.013
	CD (P = 0.05)	0.0361	0.0339	0.0349	0.0029	0.0286	0.000	0.0508

Data are presented as Mean ± SD (n = 5 specimens per location); SE(m) ± = standard error of mean; CD (P = 0.05) = critical difference at the 5% level of significance.

Table 7: Variation in body morphometric characters among *Tetragonula* populations collected from different locations in Odisha, India.

<i>Tetragonula</i> population	Sampling location	Head length	Thorax length	Abdomen length	Total body length
1. <i>Tetragonula</i> sp.	Gadagovindpur	1.168 ± 0.020	1.436 ± 0.017	1.388 ± 0.002	3.488 ± 0.018
2. <i>Tetragonula</i> sp.	Dhenkanal	1.204 ± 0.012	1.479 ± 0.007	1.433 ± 0.007	3.618 ± 0.024
3. <i>Tetragonula</i> sp.	Gulehi	1.155 ± 0.013	1.433 ± 0.016	1.361 ± 0.016	3.475 ± 0.039
4. <i>Tetragonula</i> nr. <i>pagdeni</i> (Schwarz)	Ghatikia	1.219 ± 0.014	1.475 ± 0.015	1.437 ± 0.005	3.626 ± 0.019
5. <i>Tetragonula</i> sp.	AICRP on Honeybees and Pollinators, Dept. of Entomology	1.145 ± 0.012	1.433 ± 0.009	1.384 ± 0.007	3.499 ± 0.026
6. <i>Tetragonula</i> sp.	College of Agriculture Lawn, OUAT	1.170 ± 0.011	1.457 ± 0.009	1.376 ± 0.026	3.521 ± 0.018
7. <i>Tetragonula</i> sp.	Udayagiribihar (OUAT Vatika)	1.157 ± 0.019	1.435 ± 0.011	1.375 ± 0.005	3.513 ± 0.042
	SE(m) ±	0.006	0.005	0.005	0.012
	CD (P = 0.05)	0.01	0.01	0.01	0.03

Data are presented as Mean ± SD (n = 5 specimens per location); SE(m) ± = standard error of mean; CD (P = 0.05) = critical difference at the 5% level of significance.

4. Conclusion

The study revealed considerable morphometric variation among seven *Tetragonula* populations collected from Gadagovindpur, Dhenkanal, Gulehi, Ghatikia, AICRP on Honeybees and Pollinators, Department of Entomology, College of Agriculture Lawn, OUAT, and Udayagiribihar (OUAT Vatika), Odisha. The Ghatikia population of *Tetragonula* nr. *pagdeni* generally exhibited larger dimensions for several head, antennal, wing and leg characters, whereas the Gulehi population showed comparatively smaller dimensions for many characters. Dhenkanal also recorded higher values for several leg and body characters. Hamuli number remained constant at five, while the tarsomere number remained constant at four across all populations. The observed morphometric variation provides useful baseline information for population comparison and supports further taxonomic assessment of *Tetragonula* populations in Odisha.

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