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New Records of Species Genus *Ceratina* Latreille, 1802 (Hymenoptera: Apidae: Xylocopinae: Ceratinini) from Sindh, Pakistan

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Abstract

This paper relates new provincial records of *Ceratina hieroglyphica* Smith, 1854, and *Ceratina smaragdula* (Fabricius, 1787) in Sindh, Pakistan. This study addresses a regional knowledge gap, as the *Ceratina* fauna of Sindh has not been previously documented. Thus enlarging the distribution of *Ceratina* within the region. Hand-net sampling was done in several habitats around Tandojam and in nearby localities, and specimens were stored in ethanol and later examined morphologically. High-resolution habitus imaging captured characters diagnostic of each species and were compared to a known taxonomic literature, with identifications confirmed using established taxonomic keys. The *C. hieroglyphica* can be characterized by the dark brown colouring of its body with characteristically distinct yellow markings, as well as by the presence of a triangular clypeal, which is predominantly dark brown with a yellow band, whereas the *C. smaragdula* has a metallic green exoskeleton with a distinctive yellow clypeal mark. These results present new morphological diagnoses and prove the presence of the two species in Sindh, which is added to regional biodiversity data and can serve as the groundwork for further biographical and ecological studies. Its morphological identification should be supplemented by integrating molecular techniques in future studies in order to exemplify species delimitations. The study contributes to strengthening the native fauna of pollinators from Sindh province and adds verified species of the genus Ceratina, and it will help to understand the agro-ecological zones of Pakistan.

Keywords: Hymenoptera, Apidae, *Ceratina hieroglyphica*, *Ceratina smaragdula*, small carpenter bees, morphology, taxonomy, new provincial record, Sindh, Pakistan.

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Introduction

Ceratina Latreille, 1802, Colleagues, frequently referred to as the small carpenter bees, inhabits the subfamily Xylocopinae, the tribe Ceratinini, and the Apidae (Ghosh et al., 2023). There are about 376 known species in the genus assigned into 23 subgenera and found all over the world. (Michener, 2007; Terzo et al., 2007; Roig-Alsina, 2013). The specimens are normally small and slender and their length can be more than 2.2 to 12.5 mm and may vary in color between metallic green to black and normally with a distinct yellow facial marking.

Ceratina alone represents Ceratinini and is, therefore, of particular interest in making inferences about the evolutionary transition between a solitary and social mode of life. Majority of species are solitary although some species are naturally gregarious and others are apt to developing social traits as a result of rearing in experimental environments (Rehan et al., 2016; Rehan and Richards, 2010). This whole variation in behavioral patterns offers useful resources in investigating the process and limitations affecting the advancement of sociality (Cook et al., 2019).

The diversity and distribution of *Ceratina* has not been studied in many parts especially in Sindh, Pakistan. van der Vecht (1952) analyzed (type material of) several museum collections to elucidate the identities of, and diagnostic characters of, *C. smaragdula* and *C. hieroglyphica*. In the former, he affirmed vivid green color, unusual clypeal shape and strong sexual dimorphism with males having black spots on abdomen and females lacking it and reported Karachi as an authenticated locality in the present day Pakistan. In the latter case, he fixed its name by assigning a female lectotype (Hong Kong) and reported its typical black- and yellow female markings; the male had not been discovered. His revision eliminated taxonomic confusion that was long-standing, including erroneous classification of males and females of *C. smaragdula*, as separate species, and provided confirmed occurrences in Pakistan of *C. smaragdula*.

This historical background therefore forms the framework of the current paper with documentation of new provincial records of *Ceratina* species in Sindh, Pakistan, that include *C. hieroglyphica* and *C. smaragdula*. The records extend known distribution of the genus in the area and provide up-dated morphological diagnosis on the basis of recent collections. Both Ceratina hieroglyphica and Ceratina smaragdula are recorded from Sindh, Pakistan here we provide revised morphological diagnoses based upon material gathered recently.That record,and others like it, raise the level of a region poorly investigated for the genus Ceratina in small carpenter bees.Put two questions need to be studied in this work: whether these are species to be found in the native bee fauna as well as what morphological characters of significance to define then different from published descriptions but coming from parts of South Asia other than their current position (or that may pass into these areas later).What is new in this research is that these are the first confirmed provincial records for both species from Sindh, Pakistan. This is backed up by high resolution habitus imaging and consistent diagnostic criteria. This paper fills an information void in one part of a region, but conversely offers an enhanced model to use for future research about taxonomy interrelations between rates of change in ecological factors on the one hand and distribution patterns on another as related to Ceratina within Pakistan as a whole.

Methods and Materials

Collection and Preservation of Specimens

Bees were sampled from various man-made and natural habitats in Tandojam, Sindh, Pakistan using an oriental inset net, a widely-used technique for hymenopteran active visual access. Field work was carried out between April 2022 and August 2024 with monthly visits during the flowering seasons and opportunistically throughout the year at other times of bee activity.

Each individual was placed in a vial of 95–100% ethanol and then within one hour of its capture fresh ethanol added to maintain specimen quality. All specimens were labeled with detailed collection notes that included: date, locale, coordinates (if possible) and type of habitat. After this they were transferred into −20°C for long-term preservation. Collecting works in each locality normally lasted 45-60 minutes of active netting.

Morphology and Imaging

The Insect Systematics Laboratory at Sindh Agriculture University, Tandojam used a DSLR camera fitted with an 18-headed macro lens in conjunction with extension tubes for photographing images of the entire body structure each members. In order to overcome the problem posed by shallow depth-of-field intrinsic to close-up photography, focus stacks were shot which combined numbers of images captured from different adjacent planes to create a single composite image possessing full sharpness and high resolution suitable for detailed morphological study.

Specimen Identification

The identification of specimens was carried out by the use of a stereo-microscope in order to make accurate comparison external morphological features. Species identifications were confirmed using the Oriental *Ceratina* diagnostic key of van der Vecht (1952), along with comparisons to regional and global taxonomic revisions. Characteristics of the head, clypeus, thorax, wings, legs and abdomen were systematically compared with the relevant literature, both regional (south China) and worldwide, on Ceratina.

Result

Subfamily Xylocopinae Michener, 2007

Tribe Ceratinini Michener, 1944

Diagnosis: smaller, slender bees with an elevated scutellum and barrel-shaped abdomen. They have weaker mandibles than those from the tribe of Xylocopini.

Genus *Ceratina* Latreille, 1802

Ceratina hieroglyphica Smith, 1854 (Plate 01)

Diagnosis

Dark brown to black and shiny body of medium-sized bee, with yellow hair and one distinct body bands. Head dark brown bearing conspicuous yellow markings; coarse, dense punctures and medium dense hairs; vertex rough; yellow markings coarse sparse punctures; frons dark brown, yellow markings, hairy absent; coarse sparse punctures; face peltate; eyes oval, light brown with dark brown spot. Clypeus flat, without a longitudinal median carina, coarsely but not closely pitted, exposing strip along midline, and yellow clypeal band triangularly produced upwards in the centre. Antennae, scape and pedicel dark brown, flagellum light brown. Thorax slightly upright, dark brown color with yellow markings; vertex and mesoscutum densely convex, mesoscutum posterior margin dull and extremely convex punctured; with long dark brown lateral long hairs; thorax coarse separate punctures. Wing is entirely clear, transparent. Legs with coxa and trochanter dark brown, femur, tibia and tarsi yellow. Abdomen broad, subopaque, dark brown and shiny with yellow stripes; hairs yellow, fine, sparse on upper side;

markings, dots absent; corbic ulae and scopae on legs absent, tip mucronate.

Material examined.

Ceratina hieroglyphica Smith, 1854, PAKISTAN: Sindh, Hyderabad, Tandojam, 1♀, village Piyaro Behan, 25°26'25.41"N, 68°32'54.97"E, leg., Ashraf, B. 25.03.23. 1♀, Khesana Mori, 25°26'19.35"N, 68°34'49.51"E, leg. Khatri, I., 13.viii.24. 1♀, Goth Urs Khaskheli, 25°24'47.09"N, 68°32'31.44"E, leg. Rajput, Z., 30.iv.22, vegetation

Plate 01. *Ceratina hieroglyphica* Smith, 1854 **(a)** Habitus dorsal view **(b)** Habitus Lateral view **(c)** Habitus front view

Ceratina smaragdula (Fabricius, 1787) (Plate 02)

Diagnosis

It is a small to medium sized carpenter bee (length 2.2 12.5 mm), with Apiform construction and a slender, gleaming exoskeleton varying in color between dark brown and metallic green or black. The back of the body is usually smooth to lightly punctate and virtually bare of hair, with only the occasional yellow hair and slightly better defined yellow stripes on the abdomen. The head, which is usually wine-red in colour, bears prominent yellow markings of the face, coarse and dense punctures, the vertex is rough and marked with yellow patches and coarse, very sparse punctures, the frons is furnished with yellow markings and has no hair but is punctured in the same manner as the vertex, and the eyes are oval in shape and light brown with a darker brown spot. Tubercles on the pronotum stay pale whitish-yellow. The female can be identified as having a longitudinal yellow mark on the clypeus: the clypeus is protruding, with a yellow spot that is truncate on top, drawn in on the sides, and widened towards the bottom; with coarse and sparse punctures and scarce-to-no hair except the occasional sparse brown setae. The antennae are dark brown scape and pedicel and light-brown flagellum. The thorax has a very modest, sharply elevated profile, metallic green in color with black markings, and has rough and uneven punctures; some even have long dark-brown lateral tufts. Legs have a dark brown trochanter and coxa whereas the femur, tibia and tarsi have yellow and light brown segments with fine and dense setae. The abdomen is oblong to obtuse, stiff and metallic green with two short lines on the back black on the tergites 2 and 3 (faintly extended to tergite 4); fine, sparse hairs are restricted to the underside of every segment and corbiculae and scopae are absent. Apex of the abdomen is mucronate. The apical metasomal segments are also deployed by C. smaragdula to protect entrances of the nest actively.

Material examined.

Ceratina smaragdula (Fabricius, 1787), PAKISTAN: Sindh, Hyderabad, Tandojam, 1♀, Village Sajan Nahiyoon, 25°24'32.21"N, 68°30'52.96", leg. Brohi, M.U. 29.ix.22. 1♀, Latif Agriculture Farm, 25°26'46.58"N, 68°32'8.04"E, leg. Rajput, Z., 21.iv.22, vegetation.

Plate 02. *Ceratina smaragdula* (Fabricius, 1787)
(a) Habitus dorsal view **(b)** Habitus Lateral view **(c)** Habitus front view

Discussion

New contribution lies in the direct benefit of understanding *Ceratina* biogeography within South Asia. They indicate that the distribution of small carpenter bees there is broader and more complex than has been known from previous work. Similar recent attempts in adjacent areas, such as or more records of new *Ceratina* sp. from India, indicate that *Ceratina* diversity is dynamic. As new surveys go on, we continue to add just through geographic discovery ranges of species that were previously not known from anywhere in the subcontinent (Ghosh et al., 2023; Yogi & Khan, 2020). With Sindh added as an established locality for *C. hieroglyphica* and *C. smaragdula*, the possibility that these species can track across Pakistan and into western India rests on ecological continuity. And the following of common climatic conditions is suspected to produce correspondingly composed assemblages of nectar plants Nonetheless, these findings contribute to filling in biogeographical gaps and at the same time give a more complete picture of what Ceratina species are present across South Asia's various landscapes. Our findings extend the known range of these species into Sindh, providing valuable data points for future large-scale biogeographical analyses and ecological modeling (Vargas et al., 2023). The specimens were collected from agricultural fields of Tandojam, which provides the typical foraging habitat for *Ceratina* species in South Aisa.

From an argumentative perspective, while the morphological approach is effective, the field of systematics increasingly benefits from an integrative approach. Although this study primarily utilized morphological data, future research could incorporate molecular techniques to further validate species delimitations, especially given that morphology alone can sometimes pose challenges for distinguishing closely related species (Sousa et al., 2021).

The foundational work by van der Vecht (1950) established the presence of these bees but the data for these species in the region are limited. This gap highlights the need for continued taxonomic surveys coupled with molecular and ecological studies to fully characterize their distribution, understand their population structures, and investigate their social dynamics in Pakistani ecosystems. Such integrated research would provide a more comprehensive picture of their biodiversity and evolutionary roles.

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