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A NOTE ON THE REDISCOVERY OF THE SAND WASP *BEMBECINUS PROXIMUS* (HANDLIRSCH) FROM AN URBAN HABITAT

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ABSTRACT

The wasp species *Bembecinus proximus* was described by Handlirsch (1892) but the type locality of the specimen remains inconclusive and was supposed to have been collected from Barrackpore, West Bengal, India. The species is known to be distributed in Saudi Arabia, Pakistan, Nepal, Sri Lanka and India, but the current status of the genus and the species in India remains uninvestigated since the last publication of the species by Krombein 1984. This species has been rediscovered from India after a span of more than three decades from an urban roof-top garden and its ecological role in the urban habitat has been briefly explored and explained. *Ziziphus mauritiana* has been first reported as its nectaring plant. The significance of these artificial green habitats for urban entomofaunal conservation has been highlighted.

Key words: *Bembecinus proximus*, Bembicinae, Bembicini, Crabronidae, digger wasp, rediscovery, rooftop garden, urban green space, urban entomology, urban ecosystem, habitat, wasp

Bembecinus is a worldwide genus comprising of 195 described species of sand wasps of the family Crabronidae Latreille, 1802, subfamily Bembicinae Latreille, 1802 and tribe Bembicini Latreille, 1802 (Guala and Döring, 2021). The members of this genus are collectively known as sand wasps since they prefer towards nesting in sandy areas. Majority of the species are specialist predators, known to prefer a vast range of homopteran prey species, encompassing the families Cercopidae, Cicadellidae, Cixiidae, Delphacidae, Flatidae, Fulgoridae, Issidae, Membracidae, Nogodinidae, and Tropiduchidae (Evans, 1955; Evans and O'Neill, 1986; Zolda and Holzinger, 2002; Gess and Gess, 2014; Gess et al., 2015) and occasionally visits flowers for collecting nectar (Gess and Gess, 2014). The Crabronid wasps are known to have ecological importance of being active predators that influences the prey population dynamics, and efficient pollinators (Brock et al., 2021), however the ecological role of the species *Bembecinus proximus* is not well known and requires further investigation. What can be deciphered from the existing literature is that, this species is a very efficient homopteran predator and can thrive in stochastic habitats (Gess and Gess, 2014). A single individual of *Bembecinus*, at an average, has been recorded to predate over 40 prey individuals to satisfy the requirement for a single nest cell, by virtue of which it exerts a considerable effect on the neighbouring entomofaunal population (Gess and Gess, 2014). Along with morphological similarities, *Bembecinus* shows certain behavioural uniformity in terms of the pattern of mating behaviour, nest construction, territorial aggression in females, progressive provisioning and clustering aggregation, which also adds to the pronounced uniqueness of the genus (Evans, 1955; Evans and Matthews, 1974). Very less behavioural diversity is observed in the genus, with only few species-specific variations in certain aspects like preference of nesting site and selection of prey species is documented, which, like many other wasps, may in turn be dependent on the local geography and landscape composition (Zolda et al., 2001; Steckel et al., 2014).

Hence this species, by virtue of different trophic strategies, exerts an umbrella of ecological impacts from pollination to predation to intra and inter-guild competition. In the past 20 years, only few revisions and distributional checklists have been published discussing the occurrence of *B. proximus* from the Palaearctic realm (Schmid-Egger, 2004), Afrotropical realm (Gadallah et al., 2013), Indo-Australian region (Van der Vecht, 1949), and Indomalayan (Oriental) realm (Krombein, 1984). Currently no publication has focused on the spatio-temporal distribution, species diversity, ethological or ecological aspects of *Bembecinus* in

India. With urbanization being one of the major drives of environmental changes in the present century, habitat fragmentation and lack of habitat heterogeneity in urban areas have become a very powerful phenomenon which is driving to change the distribution and occurrence of insects (Tscharntke et al., 2002; Steffan-Dewenter and Schiele, 2008; Steckel et al., 2014; Montagnana et al., 2021). Roof tops provides a barren area that can be modified to form a habitat echelon which can be utilized by many organisms, mainly in the urban setup (Fernández and González, 2010). These urban artificial green patches have been found to provide a novel habitat for insects and other arthropods (MacIvor and Lundholm, 2011; Schindler et al., 2011; Williams et al., 2014; Steck et al., 2015; Gonsalves et al., 2022). This study was conducted as a part of the project undertaken by iForNature- Nature Club, with an aim to understand the spatio-temporal distribution of entomofauna in the fragmented artificial urban habitats like roof-top and balcony gardens.

MATERIALS AND METHODS

The study was conducted from the month of June to September 2020, on the rooftop garden of iForNature – Nature Club, Kolkata, West Bengal (22°38'34.2"N; 88°25'47.2"E), located at 815m away from Netaji Subhas Chandra Bose International Airport, Kolkata, West Bengal, India. A single male specimen was collected using a swipe net, mounted on entomological pins, dried and appropriately labelled. Later on, the dried specimen was examined to note the morphometric features and confirm the species identification. Across the study period, the authors documented 5 individuals of the species of which three were males and two females. The identification of the specimen was further confirmed by Dr. Christian Schmid-Egger based on microphotographs sent to him. Furthermore, the lectotype and the paralectotype of *Bembecinus proximus* in Naturhistorisches Museum Wien (Museum of Natural History Vienna [MNHV], Austria) was examined from microphotographs. The photographs of the live specimen have been captured by SONY alpha-58 (SLT-A58) camera with Sony 55-200 mm f/4-5.6 SAM DT Telephoto Zoom Lens (Fig. 3a). The images of the preserved male specimen (Fig. 1) have been captured using Radical Stereo Zoom Trinocular Microscope -RSM-9F (180x magnification) with circular Led illuminator- Mfg. No. B201116 (Radical Scientific Equipments Pvt. Ltd., Ambala Cantonment, Haryana, India) and Hayear 41 megapixels HDMI microscope camera with 0.5x trinocular adapter (Shenzhen Hayear Electronics Co. Ltd., China). Images were further processed using the Hayear IC Measure Software supplied by the manufacturer. Measurements were calibrated using Erma Stage Micrometer (1mm -100 divisions) Model-Galaxy SMM101 (Erma Inc., Yushima, Bunkyo-ku, Tokyo, Japan). The voucher specimen was deposited to the entomological collection of the Department of Zoology, University of Kalyani, West Bengal, India. To understand the community composition of pollinators in the rooftop garden the Plant-Pollinator interactions were noted and a weighted bipartite network (Fig. 2) was constructed using RStudio software, R-package bipartite, using the function *plotweb* and the function *networklevel* was used to calculate different indices (Dormann et al., 2008).

RESULTS AND DISCUSSION

Material examined: 1♂ (Figs 1(a)-1(k)), iForNature - Nature Club rooftop garden, Kolkata, West Bengal, INDIA, (22°38'34.2"N, 88°25'47.2"E), 21.ix.2020, A. Chakrovorty. Type material: (Images): Lectotype ♂ (Fig-3c left), India: no specific locality, Handl (irsch) collection, 1892, designated by Krombein, 1984, MNHV; Paralectotype ♀ (Fig-3c right), India: no specific locality Handl [irsch] collection, 1892, designated by Schmid-Egger, 2001, MNHV.

Diagnostics: The body length of the male specimen (N=1) is 8.19 mm. Measurements of the head: (A) Length of the head- 1.5 mm; (B) Width of the head- 2.28 mm; (C) Length of the clypeus- 0.4 mm; (D) Width of the clypeus- 0.83 mm; (E)Clypeo-antennal distance- 0.14 mm; (F) Width of the face at upper clypeal margin- 0.55 mm; (G) Height of the compound eye- 1.4 mm; (H) Width of the compound eye- 0.88 mm; (I)Inter-antennal distance- 0.17 mm; (J) Inter-ocellar distance- 0.39 mm; (K) Face width at the upper edge of posterior ocelli- 1.27 mm; (L) Oculo-ocellar distance- 0.34 mm; (M)Length of the scape- 0.56 mm; (N) Length of the antenna from the pedicel- 2.49 mm (Fig. 3a) Measurements of the legs: Foreleg: (O-i) Length of the femur from the base of the coxa- 1.07 mm; (P-i) Length of the tibia- 0.9 mm; (Q-i) Length of the tarsus upto the base of the claw- 0.88 mm; Midleg: (O-ii) Length of the femur from the base of the coxa- 1.42 mm; (P-ii) Length of the tibia- 1.05 mm; (Q-ii) Length of the tarsus up to the base of the claw- 1.23 mm; Hindleg: (O-iii)Length of the femur from the base of the coxa- 1.62 mm; (P-iii) Length of the tibia- 1.65 mm; (Q-iii)Length of the tarsus up to the base of the claw- 2.03 mm; (R) Tibial spur- 0.29 mm to 0.48 mm. Measurements of the wings: (S) Forewing: Length- 5.78 mm; Width- 1.74 mm; Length of the marginal cell- 1.17 mm; Length of the free part of marginal cell- 0.35 mm; Length of 1st submarginal cell- 1.8 mm; Length of 3rd submarginal cell- 1 mm; Length of 1st medial cell- 2.5 mm; Length of radial cell- 2.21 mm; Length of 2nd cubital cell- 1.3 mm; The angle made by the posterior margin of the marginal cell with the second submarginal crossvein is 59.06˚; Angle between the margin of the marginal cell and the third submarginal crossvein is 53.59˚; The 1st and the 2nd submarginal crossveins meet on the margin of marginal cell and makes an angle of 94.67˚; (T) Hindwing: Length- 3.91 mm; Width- 0.89 mm; Length of radial cell- 3.27 mm; Length of cubital cell- 1.36 mm.

The face is bright yellow and black in colour. The ventral side of the scape and the flagellomeres are yellow coloured while the dorsal halves are black. The supraclypeal area and the area near the paraocular carinae has the continuation of the bright yellow colouration, while the paraocular area, frons and the vertex are all black in colour, consisting of small greyish-white hairs.

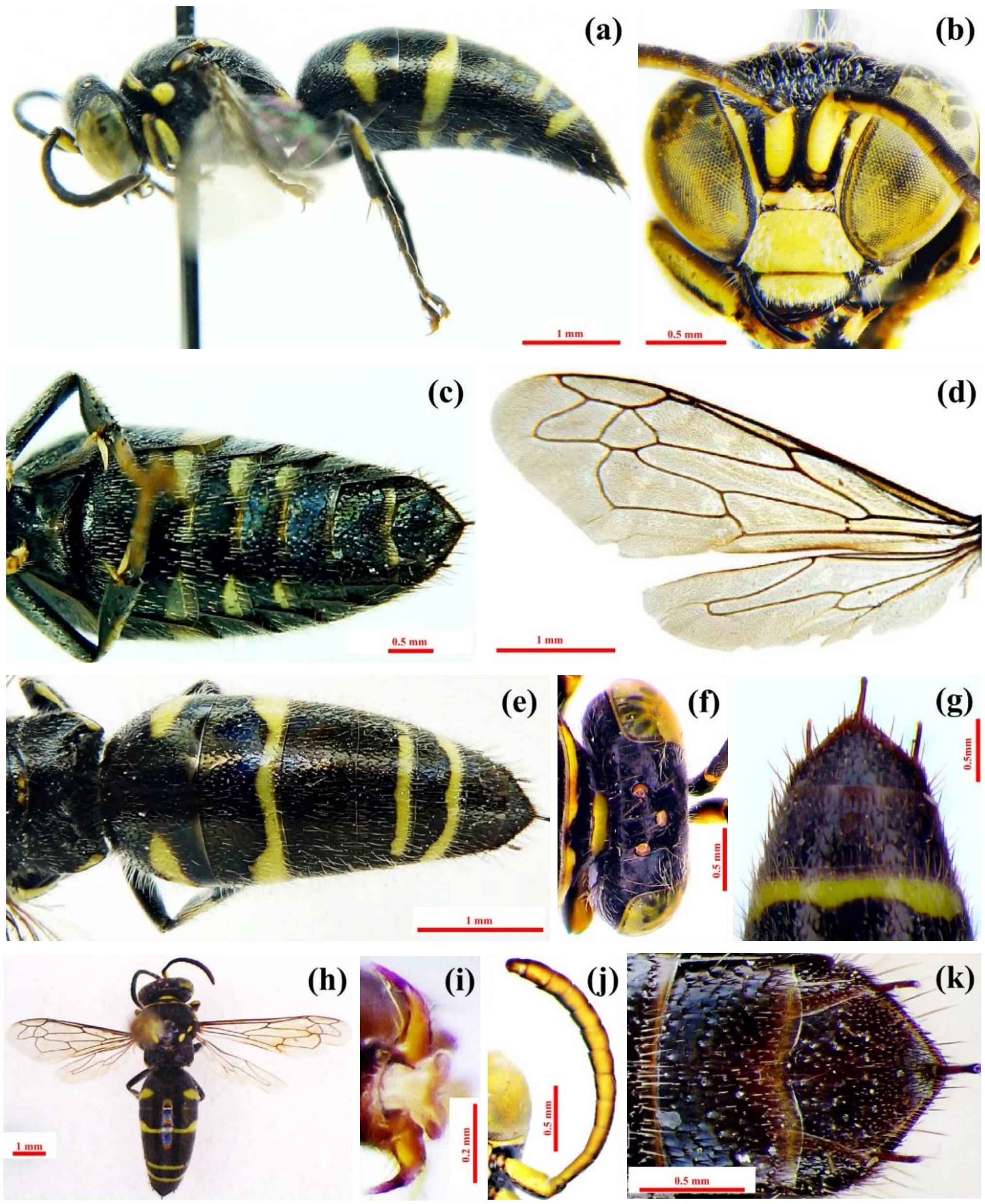

Fig. 1. Male, (a) Lateral habitus; (b) Frontal view of the head; (c) Ventral view of abdomen; (d) Wings; (e) Dorsal view of abdomen; (f) Vertex of the head; (g) Distal tergites; (h) Dorsal habitus; (i) Tarsal claw; (j) Antenna; (k) Distal sternites

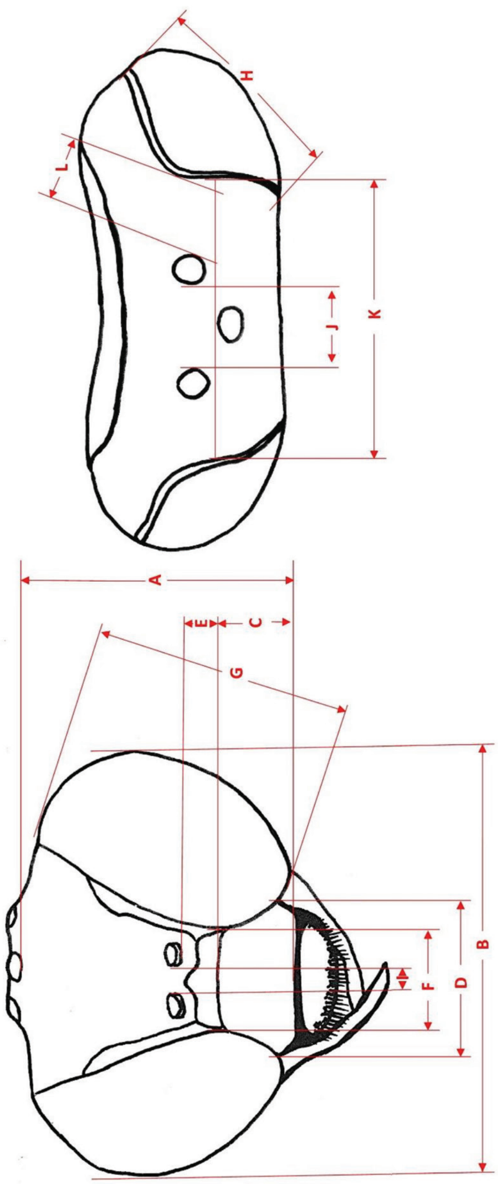

Fig. 2. Morphometric of head; Left image – Frontal view, Right image – view of the vertex

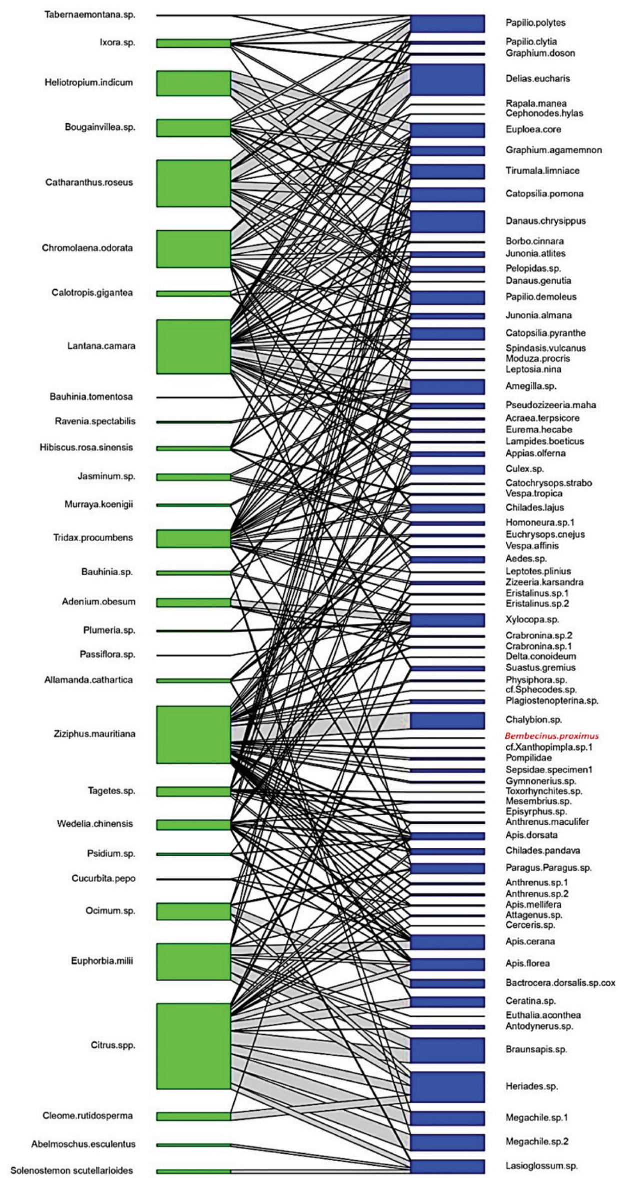

Fig. 3. Weighted bipartite network showing interaction of pollinator community - top blue panel indicates insect species and the bottom green panel indicates plant species utilized for nectaring

The clypeus and labrum are bright yellow coloured also comprising of small white hairs. Clypeus wider than its length. Flagellomere IX has a spine and flagellomere XI is curved apically. The thorax is mostly black with few bright yellow markings at distinct positions. Part of the pronotum just behind the head has a distinct yellow colouration. The pronotal collar touching the anterior margin of the scutum has bright yellow band with a slight discontinuation at the center-most middorsal area. The pronotal lobe is complete yellow. The tegula is mostly dark shade of brown with a small yellow spot anteriorly. Part of the scutum just above the posterior margin of tegula has a small yellow spot. The scutellum bears a bigger yellow spot posterior to the spot on scutum. When viewed dorsally, spots on each of the sides together makes a discontinuous V-shaped marking on the thorax. The metanotum has two yellow spots, one on each side of the middorsal line. The species has an arch-shaped unique form of propodeum with a small emargination (shallow notch). The lateral edges of the propodeum, when viewed from above, overlaps the median backside. Tip of the propodeum has yellow coloration. The foreleg femur is mostly yellow with a small elongated black mark, the tibia and the basitarsus is mostly yellow with a long black mark, meidotarsus, distitarsus and claws are yellowish-brown.

The midleg is nearly similar in coloration to the foreleg. The hindleg femur is completely black, the tibia has a small elongated oval shaped yellow mark, tarsus same as foreleg. Yellow band on tergite I is discontinuous at the mid dorsal area, appearing as lateral spots. Band on tergite II is complete and broadens laterally. Band absent on tergite III. Band on tergite IV and V are uninterrupted, but band on IV does not extend laterally, and the band on V has a flattened W-like appearance and extends laterally beyond the band on IV. Sternite II-V bears one lateral yellow water-droplet-shaped spot on each side. Body covered with long and erect silvery setae of varying lengths.

The species was observed to nest in non-friable / compacted clayey soil in the pots of the roof-top garden. The angle of the entrance makes an approximate 30˚ with respect to the upper margin of the soil. The nests were not disturbed, and the observations that were made were based on what we were able to document by observing the individuals outside the nest. It was found to predate on homopteran prey from the garden as well from areas outside the garden premises comprising of Cicadellidae and Membracidae. It carried its prey with the ventral side facing upwards, clasping onto it by its mid and hindlegs. The window of activity of the insect was observed between 7 a.m. and 6 p.m. (11 hrs ± 1.5), depending on multiple quantifiable and unquantifiable variables, displaying peak activity at around 12 p.m. (± 2 hrs). The species have been observed to be very specialised in feeding on the floral nectar of Indian Jujube (*Ziziphus mauritiana*, Rhamnaceae). The data from the bipartite plant-pollinator matrix has been presented in Fig. 2, where the blue higher level indicates the insect species and the green lower level indicates the plant species they are interacting with, and the thickness of the lines connecting them directly correlates with the frequency of interactions. The network level data obtained from the plant-pollinator interaction are as such, Connectance is 0.09578544, Web Asymmetry is 0.4257426, Link per species is 1.980198, Nestedness is 8.406265, Specialisation @symmetry is -0.1660430, Cluster Coefficient is 0.06896552, Fisher alpha value is 31.34818, Shannon diversity is 4.577003, Mean number of shared partners is 0.5089984, and the Niche overlap is 0.1527450.

Literature survey of the existing publications related to *Bembecinus proximus* has led to the indication that the distribution of the species in India is not being documented further, since the last publication by Krombein (1984). In recent years only two authors, Gadallah et al. (2013) and Schmid-Egger (2004), mentioned about the species, but none of them have collected any specimen of *B. proximus* of their own and the discussions were made based on the original specimen collected by Handlirsch, which lacks type locality and is suspected to have been collected from Assam or Bengal. Hence this study successfully documents the species from India after more than three decades and makes valuable morphological and ecological notes. Considering the current decline in entomofaunal diversity due to anthropocentric constrains, land use practices and variable biogeographic patterns, the identification and conservation of potential habitats with a significant entomofaunal diversity sustaining endemic and rare species becomes an addressable work, mainly in the urbanised setup (González et al., 2009). Urban green patches in the form of rooftop and balcony gardens have the potential to be established as an urban greenery system operating at different trophic levels, exerting a myriad of environmental benefits (Raid et al., 2017).

Research-based findings validates that these green patches can be considered as a reliable habitat restoration strategy that can be deployed in urbanised setups and can support the local entomofaunal biodiversity and which can be further utilized for

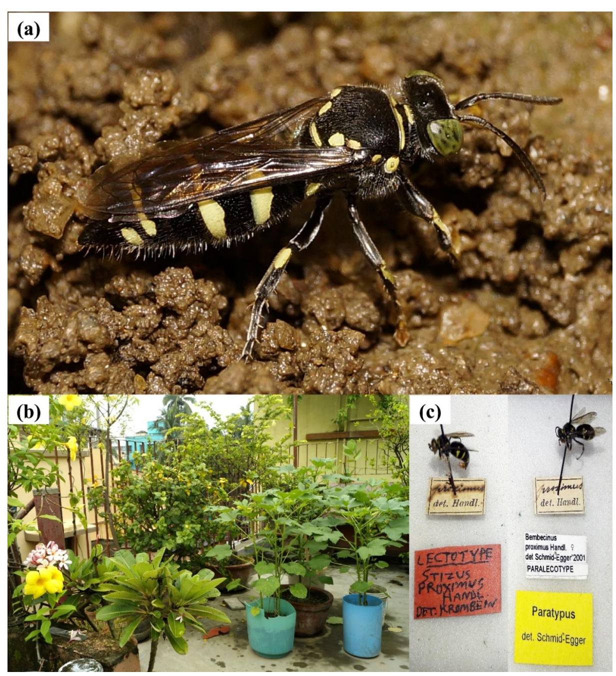

Fig. 4. (a) *Bembecinus proximus* (♀) digging its nest in the soil of the terracotta flowering pot in the rooftop garden; (b) A small section of the roof top garden at iForNature - Nature Club, Kolkata; (c) Lectotype and the paralectotype of *B. proximus*

biodiversity conservation (MacIvor and Lundholm, 2011; Schindler et al., 2011; Williams et al., 2014; Wooster et al., 2022). The rediscovery of this species along with the observed insect community from this study site, points out the ecological importance and capacity of these novel urban habitats to sustain and harbour natural entomofauna and demands further investigation to decipher the functional dynamics of these artificial green patches. Another important observation regarding this species was that unlike other *Bembecinus* species that prefers to nest in friable soil and sandy habitats (Gess and Gess, 2014), this species was observed to selectively choose clayey/ non-friable soil for nesting in the rooftop garden (Fig. 4). This study also records one nectaring plant of the species from India which is a novel ecological data for the species and has not been recorded earlier. The species interaction complexity was measured by Fisher's alpha, Linkage density, Links per species (sum of link divided by the number of species) and Shannon's Diversity indices along with connectance data indicates that there is a healthy amount of interaction amongst the species in the food web. These observation-based researches involving citizen-science and school/ college students are extremely important in the field of entomology and insect conservation as it provides us with several valuable data in terms of species distribution and occurrence, behaviour, rare morphological form and rare variants, etc, and these documentations further become a valuable addition to the knowledge pool of insect biology (Kadas, 2006; Wheeler, 2008; Schmid-Egger, 2009; Silvertown, 2009; Sullivan et al., 2014; Steinke et al., 2017; Chakrovorty et al., 2020; Chakrovorty and Brahma, 2020; Aristeidou et al., 2021; Richter et al., 2021). It is concerning that awareness about insects lacks proper implementation at basic levels like schools and colleges. We believe that this research would interest citizen-science programs and future researchers to further investigate similar artificial urban green patches in order to understand the dynamics and the role played by hymenopteran predators like *Bembecinus* in these artificial stochastic green patches and how they are influencing these habitats. This research is also expected to provide an awareness for conservation of greenery in urban areas and would be able to inspire school students and citizen scientists to promote the construction of artificial gardens and allow them to have an in-hand experience to explore the insect diversity and decipher valuable research findings not known till date.

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AUTHOR CONTRIBUTION STATEMENT

AC has conceived and executed the research. BB has analysed the data. AC, BB and AS has wrote the manuscript. AS has edited the manuscript. PC has maintained the rooftop garden and noted scientific observations.

CONFLICT OF INTEREST

No conflict of interest.

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