

**Diversity of *Xylocopa* spp. (Hymenoptera: Apidae) in
Northwest Himalayan Range of J&K and Ladakh**

Umer Bin Farook
(2019-868-D)



Division of Entomology
Faculty of Agriculture

**Sher-e-Kashmir University of Agricultural Sciences &
Technology of Kashmir**

2022

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Thesis

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in partial fulfillment of requirements for the award of the degree of**

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“Parents”

Someone who holds us in arms as we enter this world

Someone who encourages all our efforts and appreciate us wholeheartedly

Someone who listens patiently to our never ending doubts

Some who’s eyes shine with pride and happiness at our every little achievement

Someone who helps us to smile instead shedding a tear

Someone who is our life-long friend

DEDICATE MY THESIS

“To serve whom was my dream and

Dream of serving them remain forever”

“MY BELOVED PARENTS”

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
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Certificate – I

This is to certify that the thesis entitled, “**Diversity of *Xylocopa* spp. (Hymenoptera: Apidae) in Northwest Himalayan Range of J&K and Ladakh**” submitted in partial fulfilment of the requirements for the award of the degree of **Doctor of philosophy in Agriculture (Entomology)**, to the **Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** is a record of bonafide research work carried out by **Mr. Umer Bin Farook (Regd. No. 2019-868-D)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that information received during the course of investigation has duly been acknowledged.

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Certificate – III

This is to certify that the thesis entitled, “**Diversity of *Xylocopa* spp. (Hymenoptera: Apidae) in Northwest Himalayan Range of J&K and Ladakh**” submitted by **Mr. Umer Bin Farook (Regd. No. 2019-868-D)** to the **Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** in partial fulfilment of the requirements for the award of the degree of **Doctor of philosophy in Agriculture (Entomology)** was examined and approved by the Advisory Committee and External Examiner on

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Title of the Thesis : **“Diversity of *Xylocopa* spp. (Hymenoptera: Apidae) in Northwest Himalayan Range of J&K and Ladakh”**

ABSTRACT

Large carpenter bees (*Xylocopa* spp.) are generalist pollinators of wide geographical distribution. The genus *Xylocopa* Latreille (Xylocopinae: Xylocopini) comprises approximately 375 species of large, robust bees, superficially resembling bumble bees (Apinae: Bombini), that are distributed throughout the world. Two species viz., *X. valga* and *X. violacea* have been reported from the temperate zone of north western Himalayas but the key information regarding their nesting biology, morphometry and ecological studies in these regions is scanty. The taxonomic description and periodic revision of *Xylocopa* besides the molecular phylogenies are important for a region to know the available bee fauna viz a viz., addressing various biological issues such as relationship among species or genes, demographic changes and their migration patterns. The present investigation entitled **“Diversity of *Xylocopa* spp. (Hymenoptera: Apidae) in Northwest Himalayan Range of J&K and Ladakh”** was thus carried out on taxonomic review, molecular phylogeny, floral resources and nesting biology of different species of *Xylocopa*. During the investigation, a total of four *Xylocopa* species viz., *X. fenestrata*, *X. valga*, *X. pubescens* and *X. dejeanii* were recorded from UT of J&K and Ladakh. Taxonomic keys provided

the clear cut easy recognition of both sexes of these bees. The morphological description emphasized on the size, colouration, punctuation, pubescens and distinct structural characters of these bees. Cytochrome Oxidase subunit 1 (*COI*) (621 base pair length) from native *Xylocopa* fauna were amplified and sequenced for molecular phylogeny analyses. The tree topology clearly differentiated four sub-genera viz., *Xylocopa*, *Koptortosoma*, *Ctenoxylocopa* and *Zonohirsuta*. The *Xylocopa* spp. are polylectic in nature and feeds on various plants. A total of fifty-three species of flowering plants in 10 families viz., Asteraceae (11 spp.), Cucurbitaceae (3 spp.), Fabaceae (4 spp.), Lamiaceae (11 spp.), Rosaceae (10 spp.), Solanaceae (4 spp.), Oleraraceaea (1 sp.), Bignoniaceae (2 spp.), Rutaceae (3 spp.), Malvaceae (4 spp.). were found associated with four species of *Xylocopa*. To study the nesting behaviour of *X. valga*, wooden blocks, dried logs of apple/pear and bamboo sticks were installed manually. The devised artificial nesting structures except bamboo sticks provided nesting shelters for this pollinator. The study revealed maximum invasion of *X. valga* in wooden logs of Apple, Pear and Poplar. The nesting architecture revealed average nest length of 29.50 ± 1.84 cm. The number of cells per nest ranged from 5-9 with a mean of 7.17 ± 2.14 per nest. The average number of galleries recorded were 2.32 ± 1.14 . An average of seven females and one male emerged from each nest. Taxonomic description provided the precise identification of this insect. High potential of artificial nesting structures providing nesting shelter to these bees can be useful in augmentation of these bees. Nesting biology of these bees is accredited to their conservation and management which would lead to increase in pollination services and decrease in costs of crop pollination in temperate, sub-tropical and cold arid conditions of UT of J&K and Ladakh.

Key words: Floral resources, molecular phylogeny, nesting biology, pollination, *Xylocopa* spp.

Signature of Student

Signature of Major Advisor

Dated: _____

Dated: _____

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*R*esearch is an evolving concept. Any endeavor, in this regard is challenging as well as exhilarating. It implies the testing of our nerves. It brings to light our patience, vigour and dedication. Every result arrived at is a modest beginning for a higher goal and no work can be termed as a one-man show. It needs the close cooperation and guidance of experts in the field to achieve something worthwhile and substantial.

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Umer Bin Farook

Place: Wadura, Sopore

Dated:

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Chapter -1

INTRODUCTION

The pollination service provided by insects are a key component of biodiversity. These form an essential part in ecosystem survival and functioning by their inevitable role that cannot be denied (Garibadli *et al.*, 2014). These not only ensure sexual reproduction but helps in stabilizing yield and maintaining genetic variability of crops thus facilitating crop resilience. Nearly 60 to 80 per cent of the flowering plants across the globe depend on animals mostly insects for pollination (Kremen *et al.*, 2007). The annual economic value of insect pollination services to agriculture worldwide worth 235-577 billion USD (FAO, 2018).

Insect pollinators are extremely diverse, with more than 16,000 pollinator bee species (Hymenoptera: Apoidea) worldwide (Kevan, 2003). Wild and domesticated non-apis bees effectively complement honey bee pollination in many crops (Hoehn *et al.*, 2008). Examples of management of non-apis species for agricultural pollination include the use of bumble bees for the pollination of greenhouse tomatoes (Hogendoorn *et al.*, 2000), the solitary bees *Nomia* and *Osmia* for the pollination of orchard crops, *Megachile* for alfalfa pollination (Westerkamp and Gottsberger, 2000), *Xylocopa* for greenhouse melons (Sadeh *et al.*, 2007) and social stingless bees to pollinate coffee and other crops (Slaa *et al.*, 2006).

Large carpenter bees (genus *Xylocopa*) are generalist pollinators of broad geographical distribution. The genus *Xylocopa* Latreille (Xylocopinae: Xylocopini) comprises approximately 375 species of large, robust bees, superficially resembling bumble bees (Apinae: Bombini), that are distributed throughout the world (Michener 2007). Species are commonly dubbed 'large carpenter bees' as most species, like their relatives among the small carpenter bees (genus *Ceratina* Latreille), typically nest in dead wood, stems, or similar cavities (Michener 2007). Their foraging is characterized by a wide range of food plants,

long season of activity, tolerance of high temperatures, and activity under low illumination levels. These traits make them attractive candidates for agricultural pollination in hot climates, particularly in greenhouses, and of night-blooming crops. Large carpenter bees have efficient pollination service in passionflower, blueberries, greenhouse tomatoes and greenhouse melons (Keasar, 2010).

Xylocopa Latreille (Apidae: Xylocopini) includes large bees with most species displaying solitary habits (Gerling *et al.*, 1989). They have a wide geographic distribution and are primarily tropical and subtropical (Hurd and Moure, 1963), with approximately 750 species worldwide (Silveira *et al.*, 2002). In India, *Xylocopa* genus comprises of 45 species in 11 subgenera (Gupta and Yanega, 2003). The Xylocopini are large and robust bees (13 to 30 mm long), that are altogether unlike other Xylocopinae in form and appearance. The principal characters of the Xylocopini are the loss of the stigma, the very long prestigma and marginal cell (Danforth, 1989), and the strongly papillate distal parts of the wings (Michener, 2000).

The Northwestern Himalayan region comprises two newly created Union territories (Jammu & Kashmir: Ladakh region) and two states of the Indian Republic *viz.*, Himachal Pradesh and Uttarakhand. Geographically, it spreads between 28⁰43'-37⁰05' N latitude and 72⁰40'-81⁰02' E longitude covering an approximate area of 33 million ha contributing 10 per cent of total geographical area of the country. The region occupies the strategic position in the northern boundary of nation and touches the international borders of Nepal, China and Pakistan (Kashyap *et al.*, 2014). Agriculture, including livestock continues to be dominant sector despite the fact that the area is exposed to adverse and harsh geographical and agro-climatic conditions. Climate of the region is conducive for growth of large variety of plants ranging from tropical to temperate due to different altitudinal ranges varying from 100 m above mean sea level (amsl) to more than 4000 m amsl *i. e.* sub-tropical to cold temperate alpine zone. In terms of bee fauna, the region has been sparsely and scantily studied though some studies

are regarding Apis and Non Apis bees but they are not enough and reliable. Regarding *Xylocopa* two species *i.e* *X. valga* and *X. violacea* are reported from the temperate zone of north western Himalayas but lack the key information like the nesting biology, morphometry and ecological studies. Thus taxonomic description and periodic revision of *Xylocopa* besides the molecular phylogenies are important for a region to know the available bee fauna *viz a viz.*, addressing various biological questions such as relationships among species or genes, demographic changes and migration patterns of *Xylocopa* spp.

Considering the increasing global need of insect pollination and decline in the pollinator community, non-Apis bees like *Xylocopa* spp. along with honey bees hold immense importance. In order to formulate the conservation policy of any species, one needs considerable amount of available information regarding its habit and habitat. The present study was aimed to generate a baseline data regarding *Xylocopa* spp. by documentation of diversity across different landscapes which in turn may help in understanding their pollination services in various agro-ecosystems across the area and thus exploring its potential for a future pollinator candidate in temperate conditions of Kashmir. The objectives of the study were:

- To explore the diversity of *Xylocopa* spp. in different agro-ecosystems of Northwest Himalayan range of J&K and Ladakh.
- To determine the floral resources of *Xylocopa* spp. in different agro-ecosystems of Northwest Himalayan range of J&K and Ladakh.
- To study the nesting behaviour of dominant species of *Xylocopa* in Kashmir valley.

Chapter-2

REVIEW OF LITERATURE

The studies on the aspects related to present investigation components concerning the morphological characters, molecular approaches, distribution and the floral resources they exploit besides their nesting biology of carpenter bees have been reported by various researchers. The available literature on the present investigation and related aspects has been reviewed and presented under following headings:

2.1 Large carpenter bees (*Xylocopa* spp.), their taxonomic description and distribution

Apidae are one of the most diverse families of bees, containing more tribes than any other family (Michener, 2007). The family Apidae contains three subfamilies, viz., Apinae, Xylocopinae and Nomadinae. The large and diverse subfamily Apinae appears to be the sister group of either the Xylocopinae or the Nomadinae (Roig-Alsina and Michener, 1993). The family contains 5811 species in the world and 219 species in India (Ascher and Pickering, 2016). As Batra (1977) mentioned, identification of Indian bee species is difficult since most reference collections are currently housed abroad in many large museums in Europe and North America. The available collections in India are in poor shape, mostly the collections made by the British before independence and deposited predominantly in just three of museums; Zoological Survey of India, Calcutta, the Forest Research Institute, Dehradun, and the Indian Agricultural Research Institute at New Delhi (Ghorpade, 2009).

The subfamily Xylocopinae constitutes collection of bees that are very diverse in size and appearance but united by a series of common characters. The subfamily includes four tribes: Manueliini, Xylocopini, Ceratinini and Allodapini (Michener, 2007). Among these Manueliini is not present in India. Xylocopinae includes two superficially very different kinds of bees - species of the tribe

Xylocopini are large to very large, robust euceriform to anthophoriform bees (large carpenter bees), whereas the other three tribes consist of small, slender, andreniform to almost hylaeiform bees (small carpenter bees).

The taxonomic hierarchy according to Integrated Taxonomic Information System (ITIS) supported by Ascher *et al.* (2008) is as follow:

Kingdom:	Animalia
Subkingdom:	Bilateria
Superphylum:	Ecdysozoa
Phylum:	Arthropoda
Subphylum:	Hexapoda
Class:	Insecta
Subclass:	Pterygota
Superorder:	Holometabola
Order:	Hymenoptera
Suborder:	Apocrita
Superfamily:	Apoidea
Family:	Apidae
Subfamily:	Xylocopinae
Tribe:	Xylocopini
Genus:	<i>Xylocopa</i> (Latreille, 1802)

The Xylocopini are large, robust bees, 13 to 30 mm long, that are altogether unlike other Xylocopinae in form and appearance. They are often confused with bumblebees (*Bombus*, in the Apinae) by the naive. *Xylocopa* (large carpenter bees) belong to the tribe Xylocopini in the subfamily Xylocopinae. They are currently grouped into a single genus, *Xylocopa* that comprises of about 750 species (Michener, 2007). *Xylocopa* bees occur in tropical and subtropical habitats around the world, and occasionally in temperate areas (Hurd and Moure, 1963). Biogeographical analyses suggested that the *Xylocopa* genus probably had an

Oriental-Palaeartic origin, and that its present world distribution resulted mainly from independent dispersal events (Leys *et al.*, 2002).

Worldwide distribution of *Xylocopa* was provided by Hurd and Moure (1963). They further gave the taxonomic keys at subgenera and species level. Michener (2007) provided the distribution pattern of *Xylocopa* in Eastern and Western hemispheres with their taxonomic keys at subgenera level. Regional distribution of *Xylocopa* bees around the world recorded by various researchers, is as follows: China (Wu, 1982); India (Ma, 1938); California (Hurd, 1955); Western Hemisphere (Hurd, 1978); Southern Africa (Eardley, 1983); Sub-Saharan Africa (Eardley, 1987); Australia (Leys, 2000); Neotropical species (Ospina, 2000); Saudi Arabia (Hannan *et al.*, 2012) and Argentina (Lucia *et al.*, 2014).

In India, forty five species and subspecies of *Xylocopa* (X.) genus *viz.*, *X. auripennis*, *X. auripennis iridipennis*, *X. nasalis*, *X. tranquebarorum concolorata*, *X. tranquebarorum tranquebarorum*, *X. cyanescens*, *X. basalis*, *X. fenestrata fenestrata*, *X. aestuans aestuans*, *X. abbotti*, *X. bryorum*, *X. coerulea*, *X. flavicollis*, *X. flavonigrescens*, *X. hafizii*, *X. minor*, *X. provida*, *X. ruficornis*, *X. separate*, *X. bentoni*, *X. punctigena*, *X. acutipennis*, *X. assimilis*, *X. latipes*, *X. magnifica*, *X. perforator*, *X. tenuiscapa*, *X. amethystina amethystina*, *X. amethystina phanerocephala*, *X. madurensis*, *X. meyeri*, *X. nigrotarsata*, *X. prashadi*, *X. ramakrishnai*, *X. remota*, *X. proximate*, *X. tranquebarica*, *X. rufa*, *X. valga*, *X. violacea*, *X. dejeanii dejeanii*, *X. dejeanii bhowara*, *X. dejeanii binghami*, *X. dejeanii nigrocaerula* and *X. dejeanii penangensis* were reported under 11 subgenera from different parts of India *viz.*, Sikkim, Darjeeling, Punjab, Rajasthan, Kumaon, Srinagar, Bareilly, Dehradun, Nagpur, Nasik, Surat, Mumbai, Goa, Trivendrum, Cochin, Kotagiri, Malabar, Chapra, Pankhabari, Assam, Alwar, Pali, Mount Abu, Delhi, Kangra Valley, Kichha, Nainital, Bijnor, Meerut, Basha Ghat, Sawai Madhopur, Kota, Hoshangabad, Belgaum, Pune, Andheri, Salsette, Bangalore, Razampeta, Palnis, Coimbatore, Madura, Kurnool, Raxaul, Bhagalpur, Pusa, Taljhari, Santhal Parganas, Orissa, Santiniketan,

Birbhum, Sagar, Shimoga, Mussoorie, Ranikhet, Nilgiris etc. varied in distribution among above localities (Gupta and Yanega, 2003).

In terms of bee fauna in Northwestern Himalayas, many studies have been conducted in different agro-ecological zones where different Apis and non-apis species have been reported. The *Xylocopa* spp. recorded in temperate conditions so far are *X. valga*, *X. fenestrata* and *X. violacea* (Raj and Mattu, 2014; Ara *et al.*, 2019), while in sub-tropical conditions *X. collaris*, *X. latipes* and *X. pubescens* were reported (Abrol *et al.*, 2012; Tara *et al.*, 2014), however no systemic work has been done in cold & semi- arid conditions of Union territory of Ladakh, India.

Some of the principal characters of Xylocopini are probably associated with large size. Among these are the loss of the stigma, the very long prestigma and marginal cell (Danforth, 1989) and the strongly papillate distal parts of the wings, long first flagellar segment, longer than the second and third taken together; distinctively short proboscis, the parts being strongly sclerotized, the post-palpal part of the galea bladelike and presumably used to cut into the corollas of tubular flowers to rob the nectar (Michener, 2007).

The Xylocopini typically have three sub-marginal cells but the first and second are sometimes partly or wholly fused owing to the disappearance of the posterior part or the whole of the first sub-marginal cross-vein. Arolia are absent, although the densely hairy plate projects somewhat between the claws. Numerous structures were illustrated by Maa (1938 and 1970), Lieftinck (1956, 1957a), Hurd and Moure (1963), Wu (1983b), and Eardley (1983).

2.2 Molecular characterization of large carpenter bees (*Xylocopa* spp.)

Phylogenetic analyses by Leys *et al.* (2000), were based on sequences of two mitochondrial genes cytochrome oxidase1 (CO1) and cytochrome b (cytb) for 22 subgenera of *Xylocopa*, resulted in three resolved clades of subgenera: a South American group (including the subgenera *Stenoxycopa*, *Megaxycopa*, and *Neoxycopa*); a group including the subgenera *Xylocopa* and *Ctenoxycopa*; and

an Ethiopian group (including the subgenera *Afroxylocopa*, *Mesotrichia*, *Alloxylocopa*, *Platynopoda*, *Hoploxylocopa* and *Koptortosoma*). Within the Ethiopian group they found a clear separation of African and Oriental taxa, and apparent polyphyly of the subgenus *Koptortosoma*.

Leys *et al.* (2002) presented historical biogeographical analyses of the genus *Xylocopa*, based on phylogenetic analyses of species belonging to 22 subgenera using two nuclear genes, elongation factor-1 α (EF-1 α) and phosphoenolpyruvate carboxykinase (PEPCK). Friedlander *et al.* (1996) reported that these nuclear genes evolved more slowly than mitochondrial genes and has an advantage to resolve deeper divergences in the phylogeny. Phylogenetic analyses by Leys *et al.* (2002) revealed three major clades of taxa: An American group with the Oriental/Palaearctic subgenera *Nyctomelitta* and *Proxylocopa* as sister taxa; a geographically diverse group (*Xylocopa*); and a group consisting of African and Oriental subgenera. Their results on ancestral area analysis showed that the genus *Xylocopa* most likely has an Oriental-Palaearctic origin and present world distribution of *Xylocopa* subgenera resulted mainly from independent dispersal events.

Kawazoe *et al.* (2008) investigated the origin of *Xylocopa* (*Koptortosoma*) *ogasawarensis* using a phylogenetic analysis of *Xylocopa*, inferred from four genes *viz.*, mitochondrial cytochrome oxidase subunit I (COI) and cytochrome b (Cytb), and nuclear elongation factor-1 α (EF-1 α) and phosphoenolpyruvate carboxykinase (PEPCK) in Ogasawara (Bonin) Islands. They suggested that subgenus *Koptortosoma* (Ogasawara Islands) is a large, polyphyletic group, within which subgenus *Alloxylocopa* (Japanese Archipelago, closest to Ogasawara Islands) was embedded. *X. ogasawarensis* emerged as the species most closely related to *Alloxylocopa* and not to Oriental species of *Koptortosoma*. They concluded that *X. ogasawarensis* and *Alloxylocopa* share a common origin and diverged after they colonized the island regions of East Asia.

Yogi *et al.* (2016) investigated the taxonomy, molecular phylogeny, phylogeography and biological attributes of the carpenter bees from Uttarakhand. The phylogeny data was obtained by using Two mitochondrial gene fragments *viz.*, Cytochrome Oxidase subunit 1 (CO1) and Cyochrome b (cytb). The CO1 gene efficiently differentiated the subgenera of *Xylocopa* genus into different clusters. Whereas, the genetic variation among the different geographical collection was more expressive in the cytb gene. The mitochondrial gene, CO1 of about 621 base pairs length was amplified in *Ceratina propinqua* and *Ceratina compacta* for molecular phylogeny analyses. The tree topology clearly differentiated four subgenera *viz.*, *Pithitis*, *Ceratinidia*, *Neoceratina* and *Ceratinula*.

2.3 Floral resources of the large carpenter bee (*Xylocopa* spp.)

Large carpenter bees are generalist pollinators of broad geographical distribution. Their foraging is characterized by a wide range of food plants, tolerance of high temperatures, long season of activity and activity under low illumination levels. These traits made them attractive candidates for agricultural pollination in hot climates, particularly in greenhouses and of night-blooming crops. Large carpenter bees gave efficient pollination service in passionflower, blueberries, greenhouse tomatoes and greenhouse melons (Kearar, 2010).

Xylocopa arizonensis foraged on *Agave schottii* mainly during the late morning hours which reflected low competitive ability and high thermal tolerance in the carpenter bees, in comparison to honey bees and bumble bees which were more crepuscular on *A. schottii* (Schaffer *et al.*, 1979). Physiological water requirements were finely balanced by *Xylocopa sulcatipes* and *Xylocopa pubescens* with the water contents of *Callotropis* nectar, possibly due to extended coevolution with this Plant (Willmer, 1988). Nectar-foraging large carpenter bees often perforated the corollas of long-tubed flowers, and thereby reached the nectaries without contact with the anthers. Such “illegitimate pollination” or “nectar theft” has been reported for *Xylocopa virginica* and *Xylocopa micans*

foraged on blueberries (Dedej and Delaplane, 2004; Sampson *et al.*, 2004). Corolla tube perforation contributed to the reproductive success of the plants in *Fouquieria splendens* (Scott *et al.*, 1993) and *Petrocoptis grandiflora* (Guitian *et al.* 1994), indicated that the nectar robbers were dusted with pollen during foraging and functioned as pollinators (Kearse, 2010).

Hogendoorn *et al.* (2000) found that tomatoes pollinated by two Australian carpenter bee species, genus *Xylocopa* (Lestis), inside a flightcage, produced fruits that were heavier and contained more seeds than the fruits produced outside the flightcage. They concluded that the efficiency of carpenter bees in pollinating tomatoes was increased by the ability of carpenter bees to buzz the anthers. Enz (2001) reported that Eastern carpenter bee, *Xylocopa virginica* enhanced pollination, fruit set and seed production of ocotillo (*Fouquieria splendens*) and Virginia bluebell (*Mertensia virginica*). *Xylocopa pubescens* pollination increased greenhouse-grown honeydew melon (*Cucumis melo*) fruit set threefold as compared to honey bee (*Apis mellifera*) pollination (Sadeh *et al.*, 2007). They concluded that in Israel, *X. pubescens* effectively pollinated melons in enclosures and was better pollinator in terms of crop yield.

In India, pollen plant resources reported for *Xylocopa latipes* and *Xylocopa pubescens* included *Cochlospermum religiosum*, *Cassia*, *Solanum* species and *Peltophorum pterocarpum* (Rao and Reddi, 1994; Kumar, 2000; Zafar, 2005), while nectar plants reported for these two bees included *Alangium salviifolium*, *Calotropis gigantea*, *C. procera*, *Bauhinia purpurea*, *B. racemosa*, *B. variegata*, *Tecoma stans*, *Pongamia pinnata*, *Crotalaria laburnifolia*, *C. verrucosa*, *Gliricidium sepium*, *Tephrosia purpurea*, *Anisomeles indica*, *A. malabarica*, *Careya arborea*, *Tribulus terrestris*, *Moringa oleifera*, *Antigonon leptopus* and *Gmelina arborea* (Raju and Rao, 2006).

2.4 Nesting behaviour and biology of large carpenter bees

Michener (1974) reported tolerance towards the adult nestmates, as one of the prerequisites for the evolution of sociality. This was facilitated when a nestmate provided help at the nest (Gaston, 1978). In return for this help, the helper was allowed to stay at the nest, to gain experience and to take part in reproductive activities (Noonan, 1981). Social nests contained a reproductively dominant forager, and her adult offspring or a formerly reproductive, guarding female (Hogendoorn and Velthuis, 1993).

Two Israeli large carpenter bees, *Xylocopa pubescens* and *Xylocopa sulcatipes* were compared in their foraging and cell provisioning behaviour by Velthuis *et al.* (1984) in Israel. Both species made foraging flights mainly during the early morning, but *X. sulcatipes* continued to forage also later in the day. *X. pubescens* jointly collected pollen and nectar, whereas *X. sulcatipes* often conducted distinct bouts for pollen or for nectar. Mixing of nectar and pollen occurred after every flight in *X. pubescens*, while *X. sulcatipes* did this only after nectar collection. This behaviour caused greater variability in the bee bread size which ultimately caused size differences in the adults. The pollen and nectar collecting trips per brood cell were higher in *X. sulcatipes* as compared to *X. pubescens*, and thus *X. sulcatipes* produced more brood per unit of time.

Nest-building behaviour of *Xylocopa violacea* was studied by Vicidomini (1996) in southern Italy, with particular attention to construction of cells, formation of the pollen paste and construction of the diaphragms. The author reported that *X. violacea* excavated their nests in dried *Arundo donax* canes; cell length varied from 14 to 20 mm; diaphragms thickness was 2 mm in middle and 4-5 mm at edges; average fecundity was 7.43 eggs per nest. In 37 additional nests, data on colour of the pollen paste and cane inter node used for nesting were also taken by author.

Dunn and Richards (2003) studied the social behaviour of *Xylocopa pubescens* in Canada. They observed that *X. pubescens* (facultatively social carpenter bee) foundresses usually nested solitarily, however, these nests became social when a second foundress (alpha foundress) successfully usurped the nest, with the original foundress (beta foundress) remained as a guard. Reproductive skew theory analysed by them, predicted that beta foundresses remained as helpers only when alpha usurpers allowed them to share of reproduction. Because alpha females destroyed much of beta's brood and beta females did not lay eggs after takeovers, they concluded that usurpers offered no staying incentives or concessions in return for helping behaviour.

Bernardino and Gaglianone (2008) reported that *Xylocopa ordinaria* nested in dry branches of *Pera glabrata*, *Sideroxylon obtusifolium* and *Eugenia ovalifolia* in Brazil. They recorded that wood availability and wood characteristics, made *P. glabrata* as the main nesting substrate, rather than its taxonomical affinity. The circumference of the nesting substrates varied from 7 to 25.5 cm and nest entrance height above ground varied from 30 to 400 cm. Nest entrances of *X. ordinaria* were elliptical in shape and nests consisted of one to four tunnels which have smooth walls. Female bees of *X. ordinaria* presented floral constancy while provisioning the brood cells.

Richards (2011) studied nesting aggregations of *Xylocopa virginica* in Canada. Nest aggregations were found in benches that were constructed of cedar boards, and entrances of nests were on the bottom. In the aggregations, most nests were social, contained groups of two to five adult female bees. In nests, social female bees exhibited several strategies inferred from mandibular wear patterns, which reflect nest construction activity, and wing wear patterns, which reflect flight activity. The author concluded that social nesting, deferred reproduction, and serial replacement of dominant females in the social nests were probably the response of bees to severe competition for nests and nesting substrates.

Biology of *Xylocopa sulcatipes* was studied by Hannan *et al.* (2012) in Saudi Arabia. Their results showed that *X. sulcatipes* foraged from March through November. *X. sulcatipes* used dried stems of *Calotropis procera* and *Phoenix dactylifera* as their nesting resources. Among these two resources, *C. procera* was the most commonly used for nesting and provisioning resources. The pithy and straight stems of suitable diameter of *C. procera* made them ideal for nest construction. Nests in *C. procera* have a single, linear nest tube extended to each side of the entrance, while nests in *P. dactylifera* consisted of a more gallery like structure.

Nesting biology of two sympatric carpenter bee species; *Xylocopa ordinaria* and *Xylocopa frontalis* was studied by Bernardino and Gaglianone (2013) in Brazil. They found that *X. ordinaria* nested throughout the year, while *X. frontalis* nested between December and April. Both species nested in *Terminalia* sp., while only *X. ordinaria* nested in *Pera glabrata* and only *X. frontalis* nested in Eucalyptus sp. and bamboo culms. Nests of *X. ordinaria* found in wider substrates had more tunnels. Nest tunnels width and brood cells dimensions were smaller in *X. ordinaria* than were observed for *X. frontalis*. Females of both species spend most of their time in activities inside the nests, followed by nectar and pollen flights, and nectar dehydration. Pollen resources used by both species presented more than 40 per cent similarity.

Zafar (2013) reported the nesting activity of *Xylocopa latipes* and *Xylocopa pubescens* in Visakhapatnam, India. The author mentioned that these species constructed their nests in dead wood or dead branches of still living plant species, namely, *Syzygium cumini*, *Cassia siamea* and *Bambusa vulgaris*. The tunnel of nest contained a series of cells. The pollen and nectar collected by female bee then deposited in each cell. The female deposited one egg in each cell and sealed the cell with partitions of saw dust cemented together with saliva. After the female has sealed all the cells, she remained at the nest entrance until the progeny emerged.

Density and distribution of *Xylocopa* nests were studied by Martins *et al.* (2014) in Caatinga areas, Northeastern Brazil in the Surroundings of passion fruit crops. They found two species; *Xylocopa grisescens* and *Xylocopa frontalis* in this area, nested in *Commiphora leptophloeos* trees. Average diameter of nesting branches was 5.3 ± 2.0 cm. Mean number of nests/tree was 3.1 ± 2.8 . The less disturbed area showed 6.7 nests/ha and 4.2 nests/tree, while disturbed areas showed 0.9 nests/ha and 2.7 nests/tree.

Nesting biology of Oriental carpenter bee, *Xylocopa nasalis* was studied by Hongjamrassilp and Warrit (2014) in Thailand. They found that *X. nasalis* constructed linear unbranched nests in open-end of bamboo culms. The nest length and the nest entrance diameter were 25.40 ± 6.95 cm and 17.94 ± 6.00 mm, respectively, and the maximum number of provisioned cells was eight. A biased sex ratio of 8♀: 1♂ was reported in nests, with up to seven offspring inhabiting in a single nest. The average weight of the faeces in the cells of post-defecating larvae was 0.24 ± 0.23 gram.

He and Zu (2020) conducted a study between July 2014 and June 2019 on nesting and foraging behaviour of *Xylocopa valga* in the *Populus euphratica* forest reserve in the Ejina Oasis, China. They found that *X. valga* builds its nests in the dead wood of *P. euphratica*. and is univoltine. They observed that females nest near each other and several females may share a single nest entrance, based on which they build their own cells. Their nests were branched. In the *P. euphratica* forest area, the food for the progeny of *X. valga* was mainly composed of the pollen and nectar of *Sophora alopecuroide* and *Populus euphratica*. Therefore, *X. valga* and *S. alopecuroides* exhibit close ecological interactions in the *P. euphratica* forest ecosystem.

Chapter -3

MATERIAL AND METHODS

The studies on “**Diversity of *Xylocopa* spp. (Hymenoptera: Apidae) in Northwest Himalayan Range of J&K and Ladakh**” were carried out between 2019 and 2021 using following methodology:

3.1 Study area

The collection cum survey tours were conducted in various localities/villages/cities situated at different Agro-ecological zones of Northwestern Himalayas of India (Table 1, 2 & 3) (Fig 1). The areas were systematically explored. Altitude and coordinates of each site were measured with digital altimeter. Sampling was carried out only once at every site dominated by the most representative vegetation types of the region.

3.2 Insect Collection/killing and illustration of photographs

Xylocopa were collected using sweeping hand/ Aerial net made up of nylon cloth. The species collected were later killed with ethyl acetate present in the killing jar. The collection was mainly on random sampling methods, covering different agro-ecosystems (Plate 1). External morphological structures were studied using a Nikon SMZ 1000 stereomicroscope. Habitus photographs were taken with a Canon D-5600 with a 100mm macro lens attached to stack shot. Multiple images (15 images) at different focal depths were taken and combined using Zeren stacker software. Genitalia structures were photographed using a Leica 205C microscope mounted with a Leica DFC450 camera and by using auto montage software. The genitalia were placed in small cavity block with glycerine for illustration. Plates were prepared using Adobe Photoshop CS6.

3.3 Processing of specimen

The specimen collected throughout the study period were brought to the laboratory, sorted, relaxed and pinned using insect pins (size No. 1, 2 and 3). Prior

to mounting the pointed end of each paper point was slightly bent using forceps to facilitate gluing on to right side of the thorax to permit examination of characters of the head, wings and abdomen. Tongue, mandibles, antennae, legs and wings were stretched properly (Plates 2,3,4,5 & 6). The processed specimens were permanently labelled giving details of locality, date of collection, host plants and name of the collector.

Table 1: Detail of locations explored for *Xylocopa* specimen collection from Kashmir valley

UT	Districts	Location	Latitude	Longitude	Altitude (m AMSL)
Jammu & Kashmir	Ganderbal	Wakura	34°13'19"N	74°41'41"E	1630
		FoF Benhama	34°16'43"N	74°46'37"E	1757
		Gutlibagh	34°16'33"N	74°49'39"E	1778
		Eco-park Manigam	34°16'40"N	74°48'41"E	1668
		Kijipora	34°16'24"N	74°53'05"E	1770
		Kangan	34°15'56"N	74°54'09"E	1811
		sonamarg	34°18'08"N	75°17'21"E	2669
	Bandipora	Ajas	34°19'56"N	74°40'24"E	1558
		Wullar vintage park	34°21'49"N	74°39'26"E	1599
		Bandipora Nishat park	34°24'51"N	74°38'36"E	1597
		Naidkhai	34°13'54"N	74°34'09"E	1581
		Vijpura	34°16'39"N	74°35'53"E	1583
	Baramulla	FoA wadura	34°20'51"N	74°24'12"E	1585
		Pattan	34°09'25"N	74°33'19"E	1599
		Achabal	34°16'21"N	74°24'11"E	1583
		Delina	34°14'20"N	74°25'22"E	1592
		Hadipora	34°17'31"N	74°24'07"E	1588

	Shopian	Pinjoora	34°43'47"N	74°51'26"E	1989
		Imam sahib	34°44'32"N	74°54'45"E	1882
		Shopian town	33°43'08"N	74°49'54.86"E	2042
		Hirpora	34°41'02"N	74°47'35"E	2269
		Balpora	33°55'37.12.3"N	74°39'15.6"E	2100
	Kupwara	Chogul	34°24'14"N	74°19'31"E	1593
		Vilgam	34°28'21"N	74°08'48"E	1784
		langate	34°18'27"N	74°17'59"E	1710
		Handwara	34°29'55"N	74°17'59"E	1590
		Nutnussa	34°26'50"N	74°17'59"E	1592
	Srinagar	Lal chowk	34°07'26"N	74°81'39"E	1586
		FoH, Shalimar	34° 08'54"N	74° 52'50"E	1600
		Chhatrahama	34°11'02"N	74°52'02"E	1671
		Mujagund	4°08'11"N	74°42'15"E	1589
		Gulabagh	34°10'52"N	74°49'18"E	1612

Table 2: Detail of locations explored for *Xylocopa* specimen collection from Jammu region

UT	Districts	Location	Latitude	Longitude	Altitude (m AMSL)
Jammu & Kashmir	Jammu	chattha campus	32°39'13"N	74°48'12"E	267
		R.S. Pura	32°36'35"N	74°44'15"E	273
		Bantalab	32°46'57"N	74°49'35"E	380
		Mansar	2°41'33"N	75°08'55"E	663
		Suransar	32°46'00"N	75°02'39"E	606
	Doda	Main Doda	33°08'33"N	75°33'03"E	1102
		Pul Doda	33°08'06"N	75°33'11"E	1010
		Kvk Doda	2°58'59"N	75°43'03"E	1607
		sartingle	32°56'57"N	75°43'44"E	1765
	Kathua	KVK Kathua	32°22'46"N	75°30'17"E	333
		KK Birla public park	2°23'42"N	75°30'52"E	364
		Barnoti	32°25'22"N	75°26'44"E	346
		Rakh lachipura	32°24'20"N	75°28'06"E	348
	Rajouri	KVK Rajouri	33°22'33"N	4°17'18"E	913
		Budhal	33°22'33"N	4°38'49"E	1785
		Saj thanamandi	33°27'24"N	74°19'49"E	1122
		Badhori, shahdara sharif	33°33'04"N	74°20'23"E	1621
	Poonch	KVK Poonch	33°46'00"N	74°06'40"E	1004
		Lassana	33°41'45"N	74°14'07"E	1248
		Dundak	33°40'55"N	74°14'53"E	1335
Naka manjheri		33°36'02"N	74°14'47"E	1242	

Table 3: Detail of locations explored for *Xylocopa* specimen collection from Ladakh region

UT	Districts	Location	Latitude	Longitude	Altitude (m AMSL)
Ladakh	Kargil	Research station kargil	34°32'19"N	76° 09'04"E	2700
		KVK Kargil	34°31'13"N	76° 08'35"E	2670
		Minjee	34°29'10"N	76° 06'06"E	2676
		Sankoo	34°17'31"N	75° 57'39"E	2630
	Leh	HMAARI	33°58'30"N	77°41'56"E	3304
		Leh park	34°08'47"N	77°34'51"E	3385
		Kuzey chuchot	34°05'37"N	77°35'19"E	3224
		Shey	34°04'08"N	77°37'56"E	3237

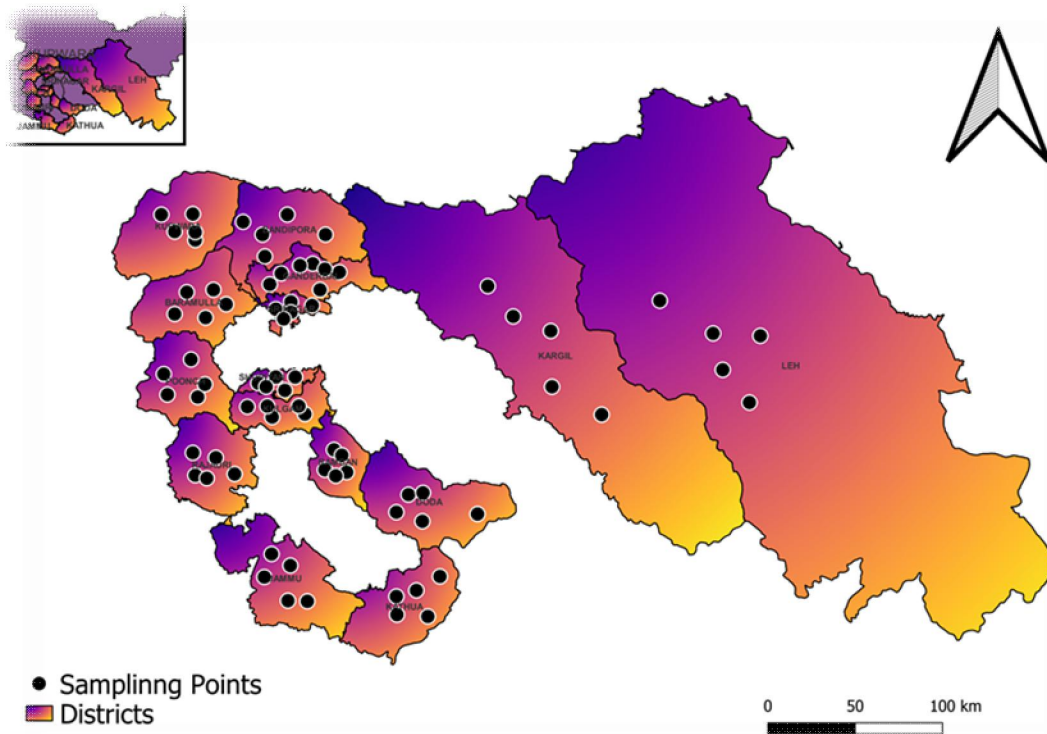


Fig. 1: Details of locations for survey



Plate 1: Insect collection at different locations of Jammu, Kashmir and Ladakh region

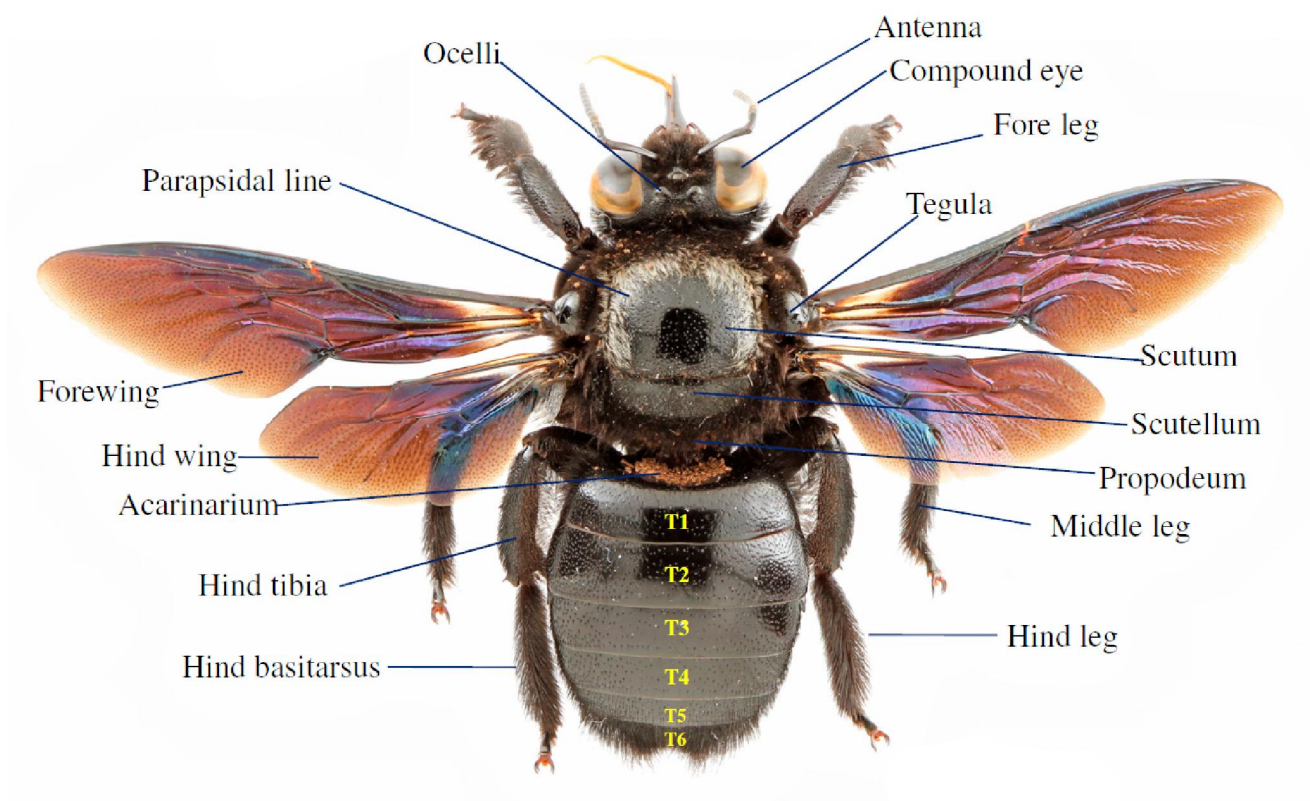


Plate 2: External morphology of large carpenter bee

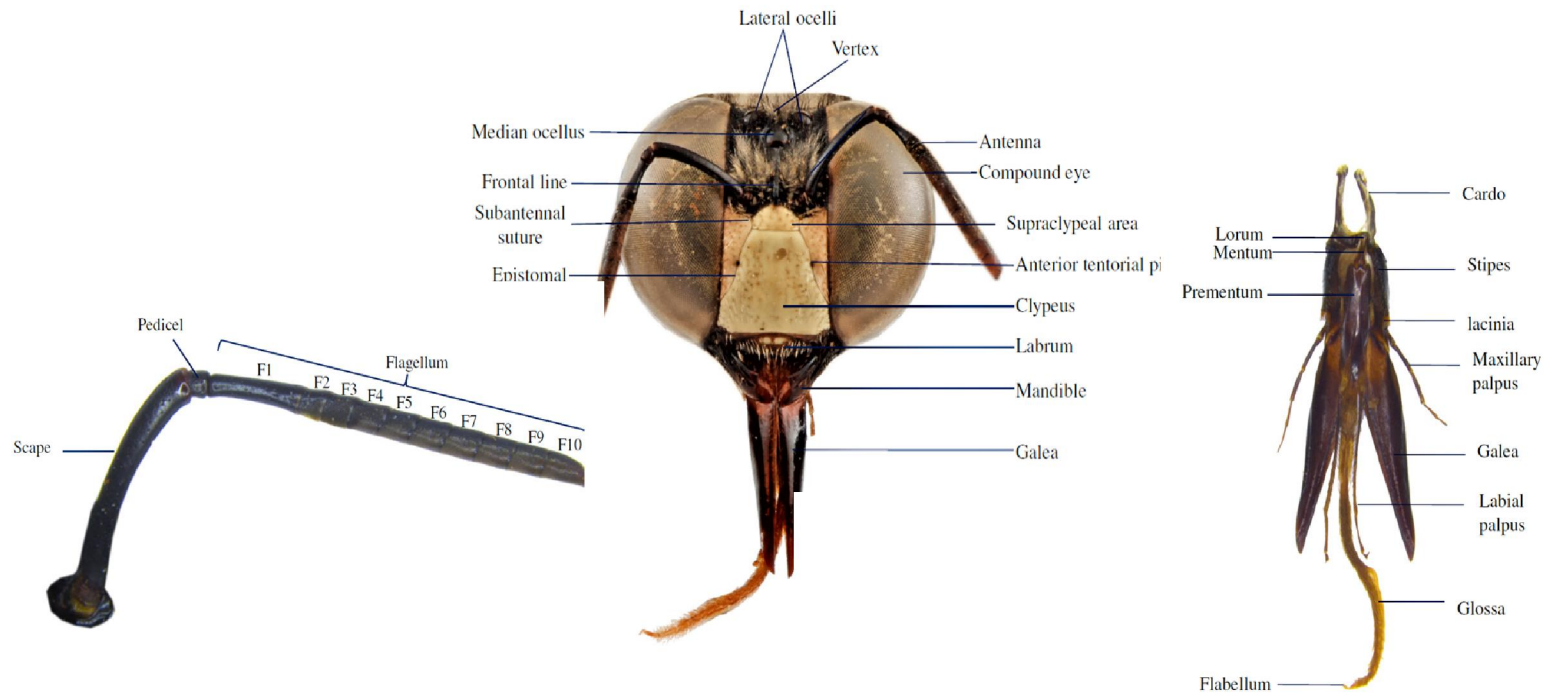
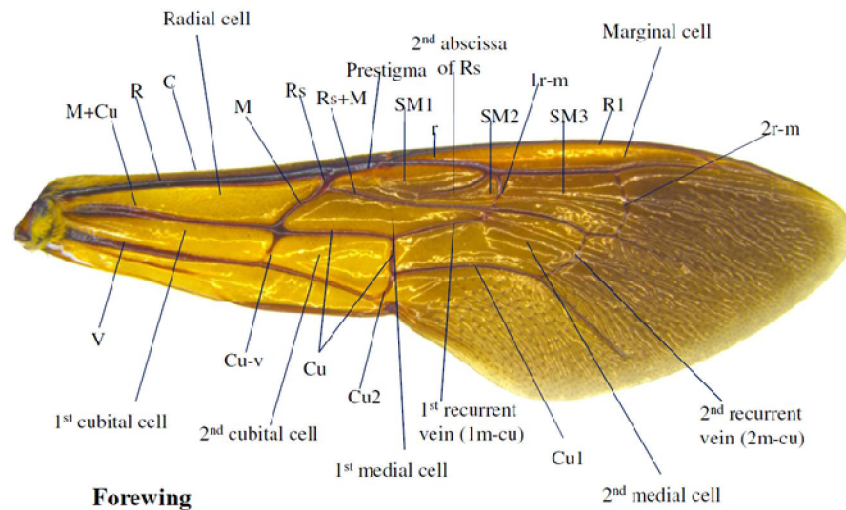
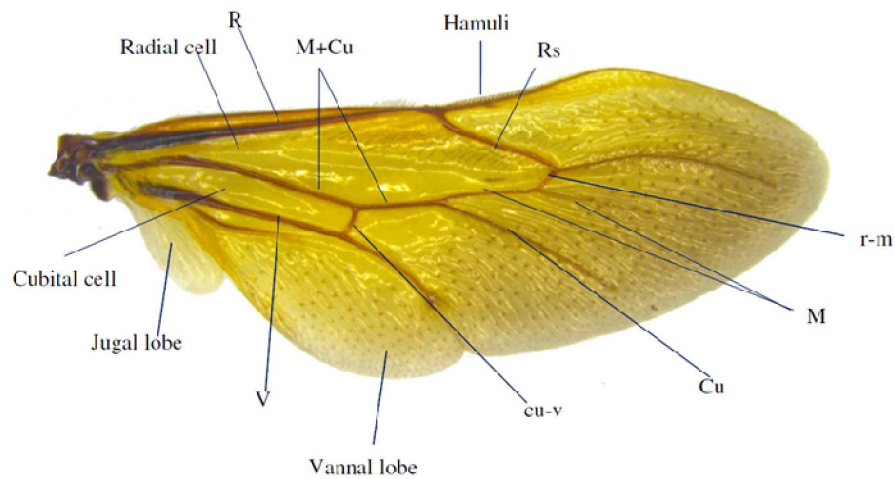


Plate 3: Morphology of head, antenna and proboscis of large carpenter bee



Forewing



Hindwing

Plate 4: Structure of carpenter bee wings

M: Basal vein; C: Costa; R: Radial vein; M=Cu: Medio cubital vein; V: Vannal vein; Cu: Cubital vein; Cu1: 1st cubital vein; Cu2: 2nd cubital vein; SM1: 1st sub marginal cell; SM2: 2nd sub marginal cell; SM3: 3rd sub marginal cell; r: Radial cross vein; cu-v: Cubito vannal cross vein; 1r-m: 2nd submarginal cross vein; 2r-m: 3rd submarginal cross vein.

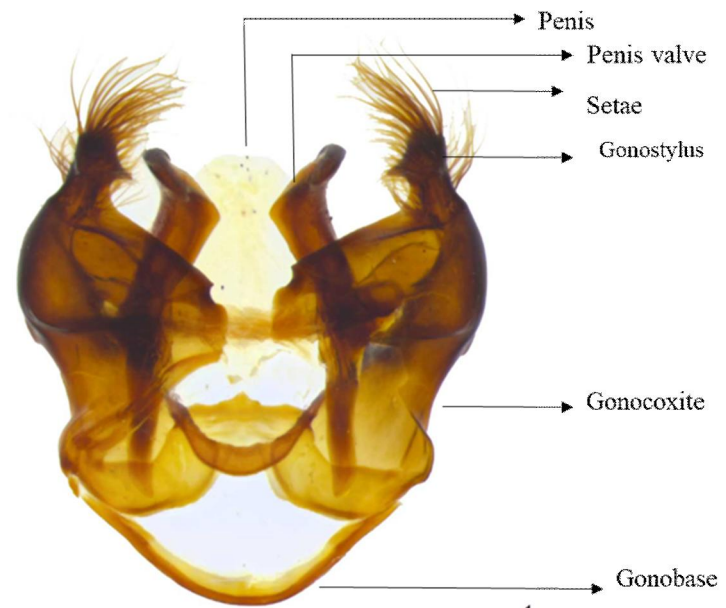
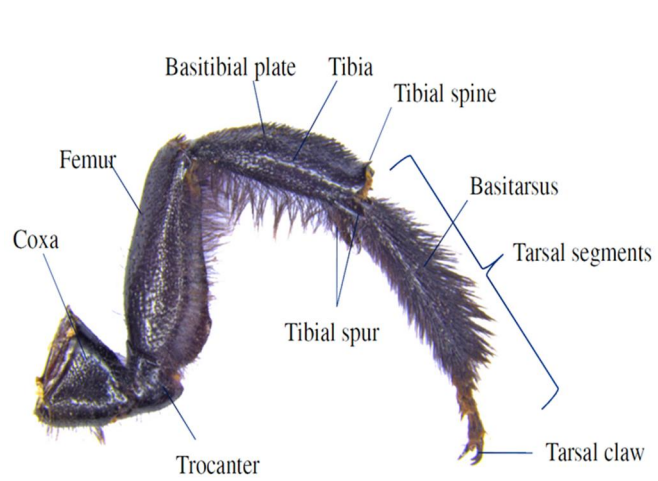


Plate 5: Structure of leg and male genitalia of carpenter bee

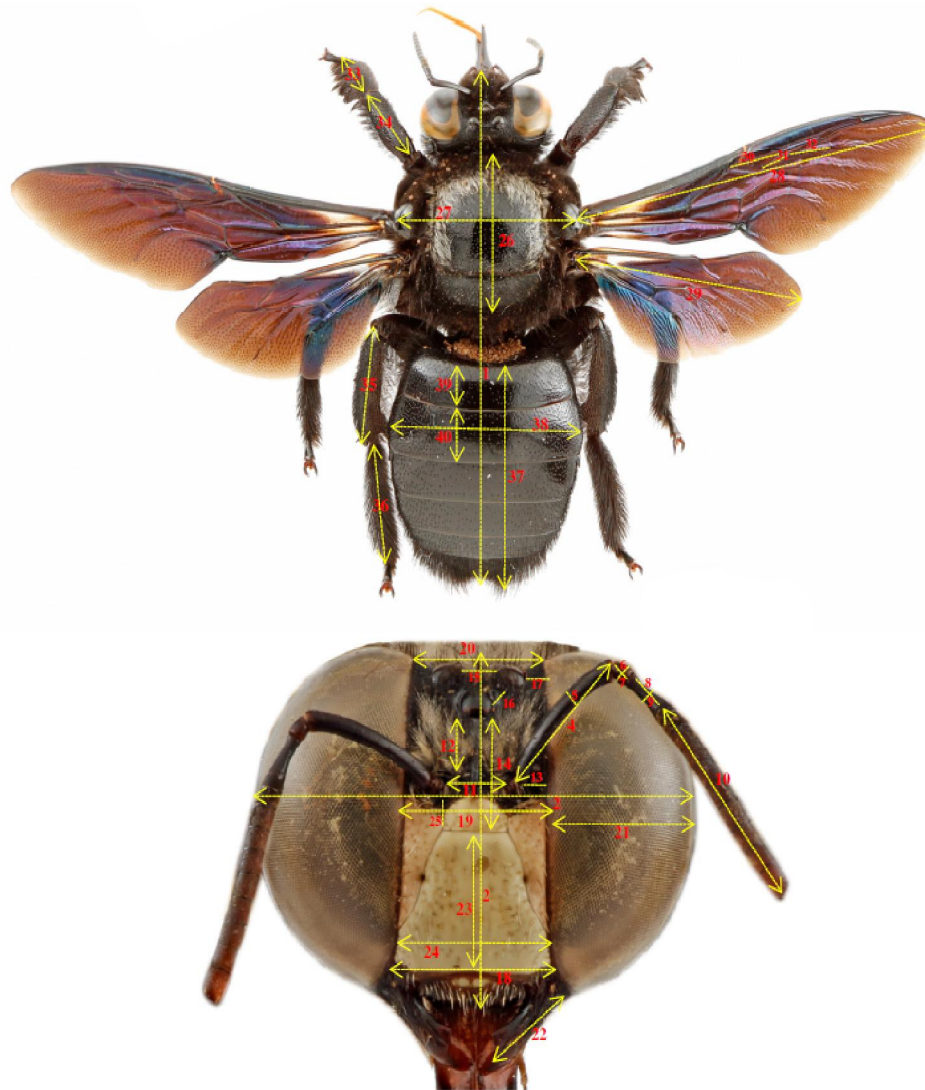


Plate 6: Measurements of body parts of carpenter bee

1. Total body length, 2. Length of head, 3. Width of head, 4. Length of scape, 5. Width of scape, 6. Length of pedicel, 7. Width of pedicel, 8. Length of F1, 9. Width of F1, 10. Length of F2-F11, 11. Inter antennal distance, 12. Antenno-ocular/alveolocellar distance, 13. Anteno-ocular/ alveocular distance, 14. Clypeocelllar distance, 15. Inter - ocellar distance (b/n lateral), 16. Inter - ocellar distance (b/n median & lateral), 17. Ocello-orbital distance, 18. Lower inter-ocular distance, 19. Mid inter-ocular distance, 20. Upper interocular distance, 21. Width of eye, 22. Length of mandible, 23. Length of clypeus, 24. Width of clypeus, 25. Clypeo-antennal distance, 26. Length of mesosoma, 27. Width of mesosoma, 28. Length of Fore wing, 29. Length of hind wing, 30. Length of 1st sub marginal cell, 31. Length of 2nd sub marginal cell, 32. Length of 3rd sub marginal cell, 33. Length of fore tibia, 34. Length of fore basitarsi, 35. Length of hind tibia, 36. Length of hind basitarsi, 37. Length of metasoma, 38. Width of metasoma, 39. Length of first matasomal segment length (T1), 40. Length of second matasomal segment length (T2).

3.3.1 Preparation of genitalia of *Xylocopa* spp.

For studying male genitalia, dissections were carried out by relaxing the specimen and detaching the metasomal segment with an insect pin and placed overnight in vials containing 10 millilitres of 15 per cent KOH. The genital capsule was carefully separated from metasomal segments in cavity block and washed thoroughly with distilled water and then transferred to another cavity block containing 70 per cent ethyl alcohol. The different skeletal parts were separated under a stereo-binocular microscope using fine forceps and a pair of hooked minute pins and placed on a cavity block with glycerol. Genitalia of each specimen was stored in a small eppendorf tube containing a few drops of glycerol and was pinned to the respective specimen for subsequent studies.

3.3.2 Taxonomic study of *Xylocopa* spp.

The sample size for morphological descriptions was two to ten specimens. Morphological terminology in the diagnoses was followed as per Michener (2007) and Eardley *et al.* (2010). Description of species was mainly on the basis of size, colouration, punctuation, *pubescens* and structural characters. As suggested by Michener (2007), regional keys were followed for the identification of bees. For subgenera level identification, taxonomic keys provided by Minckley (1998), Gupta and Yanega (2003) and Michener (2007) were used. The key to species was partially adapted from Bingham (1897), Ma (1938), Maa (1970) and Jobiraj (2002).

3.4 Molecular characterization of the *Xylocopa* spp.

After morphological identification, the specimen was further confirmed by molecular analysis as per the method described by Henry *et al.* (1990), (McWilliam *et al.*, 2013), (Tamura *et al.*, 2007), (Goloboff, 1999), (Nixon, 2002) and (Saitou and Nei, 1987) at Division of Biotechnology IARI, New Delhi.

3.5 To determine the floral resources of *Xylocopa* spp. in different agro-ecosystems of Northwest Himalayan range of J&K and Ladakh.

Floral rewards (nectar or pollen) by *Xylocopa* spp. during each floral visit were observed. The observations like extending their proboscises to the base of the corolla were reported for nectar collection while as during pollen gathering for combing anthers.

Besides, other behaviour like buzzing and nectar robbing was observed visually.

3.6 To study the nesting behaviour of dominant species of *Xylocopa* in Kashmir valley

The nesting behaviour was studied using artificial nesting structures. Wild nests and artificial nests (nests in installed structures) were collected in morning hours on sunny days to ensure that occupants were within the nest until dissection. At the nesting site, nest entrances were closed with water resistant tape and nesting branch/cane/log were detached from the plant/nesting structure. The nests were dissected in the laboratory on the same day of collection. Nests were carefully split longitudinally lengthwise to avoid injuring immatures or destroying cell septa and to expose nest contents. The pattern for numbering the cells were kept similar for all nests, 1st cell near the base which formed first by the bee and last cell near the entrance. Number of provisioned cells and surviving broods per nest were recorded.

Studies on nesting biology of *Xylocopa* spp. were covered under following observations:

1. Nesting habitat and nesting substrate
2. Nest entrance: diameter, direction, and height from ground level
3. Nest tunnel: length and diameter
4. Girth and woody thickness of nesting material

5. Number, arrangement and dimensions of cells in nest
6. Length and shape of cell septa
7. Nest contents including the provision, developmental stages and other material

Data was recorded in millimetres with mean \pm standard deviation. Statistical analyses were based on ANOVA table, one factor analysis.

3.6.1 Detail of artificial nesting structures of *Xylocopa* spp. (Plate 7)

3.6.1.1 Wooden blocks

Nests were made from the wooden blocks of Poplar (*Populus deltoids*) and Willow wood (*salix* spp.). These large blocks were cut into 300-400mm length, 150 mm width and 100 mm height. From each material two to three blocks were taken (replicated seven times), stacked and placed in a shady place for observing the bee activities.

3.6.1.2 Wooden logs

The material taken for preparing nests from wooden logs are Poplar (*populus deltoids*) Willow wood (*salix* spp.) Apple tree wood (*Malus domestica*) and Pear tree wood (*Pyrus communis*). The logs were cut into 300-350mm length and 100-150 mm diameter. The combination of two to three logs from every wood type were combined (replicated seven times), stacked, tied and kept on shady, dampless place for recording the bee activities.

3.6.1.3 Bamboo canes

Bundles of bamboo reeds installed at all the locations in seven replications with 20 to 30 mm inner diameter and 230 to 380 mm tunnel length.



a



b



c



d

Plate 7: Different artificial nesting structures used for *Xylocopa valga* at Ganderbal
a) Wooden blocks b) wooden logs c) Bamboo sticks d) combination of all

Chapter-4

EXPERIMENTAL FINDINGS

The studies on “**Diversity of *Xylocopa* spp. (Hymenoptera: Apidae) in Northwest Himalayan Range of J&K and Ladakh**” were carried out between 2019 and 2021. A total of 302 specimens were examined across various agro-climatic zones. The findings of the study are presented in this chapter.

Objective 1: To explore the diversity of *Xylocopa* spp. in different agro-ecosystems of Northwest Himalayan range of J&K and Ladakh.

The study revealed 04 species belonging to 04 subgenera of subfamily Xylocopinae.

4.1 List of taxa dealt with in this study

Subfamily: Xylocopinae

Tribe Xylocopini Latreille

Genus *Xylocopa* Latreille, 1802

Subgenus *Ctenoxylocopa* Michener, 1938

Xylocopa (Ctenoxylocopa) fenestrata (Fabricius, 1798)

Subgenus *Koptortosoma* Gribodo, 1894

Xylocopa (Koptortosoma) pubescens (Spinola, 1838)

Subgenus *Zonohirsuta* Ma, 1938

Xylocopa (Zonohirsuta) dejeanii (Lepelletier, 1841)

Subgenus *Xylocopa* Latreille, 1802

Xylocopa (Xylocopa) valga (Gerstaecker, 1872)

4.2 Taxonomy of the subfamily Xylocopinae

Key to the Species of *Xylocopa* in J&K and Ladakh

Males

- | | | | |
|---|---|---|---------------------|
| 1 | Length 28 mm or above; antenna completely black with no characteristic curve at the end | : | <i>X.valga</i> |
| | Length under 25 mm | : | 2 |
| 2 | Body with olive yellow <i>pubescens</i> | : | <i>X.pubescence</i> |
| | Body with black or sooty brown <i>pubescens</i> | : | 3 |
| 3 | Face without pale yellow marking and forewings hyaline at bases | : | <i>X.fenestrata</i> |
| | clypeus, face yellow with thin yellowish brown hairs or <i>pubescens</i> on vertex | : | 4 |
| 4 | Length 15-20 mm | : | <i>X. dejeanii</i> |

Females

- | | | | |
|---|---|---|---------------------|
| 1 | Length 30 mm or above; antenna completely black with forewing more than 18mm long | : | <i>X.valga</i> |
| | Length under 30 mm | : | 2 |
| 2 | Mesosoma covered dorsally with yellow to yellow-greenish hairs | : | <i>X.pubescence</i> |
| | Body with black or sooty brown <i>pubescens</i> | : | 3 |
| 3 | Black pubescence ferruginous along the apex of anal abdominal segment | : | <i>X.fenestrata</i> |
| | Black face with a mixture of pale and black hairs ; anterior portion of thorax dorsally and laterally with a collar of white <i>pubescens</i> | : | 4 |
| 4 | Body less than 20 mm ; wings dull fuscous with moderate purple effulgence | : | <i>X. dejeanii</i> |

4.3 Subgenus *Xylocopa* Latreille, 1802

4.3.1 *Xylocopa (Xylocopa) valga* (Gerstaecker, 1872) (Plate 8 & 9)

Apis violacea, Christ, 1791

Xylocopa valga, Gerstaecker, 1872

Xylocopa valga, F. Smith, 1874

Xylocopa valga, Alfken, 1935

Xylocopa valga, Hedicke, 1938

4.3.1.1 Material examined

INDIA: Kashmir: **Srinagar:** 5♀, Lal chowk, 34°07'26"N, 74°81'39"E, 1586m, 15.vi.2021, Umer B. Farook; 6♀, FoH, Shalimar, 34°08'54"N, 74°52'50"E, 1600m, 21.v.2021, Umer B. Farook; 7♀, Chhatrahama, 34°11'02"N, 74°52'02"E, 1671, 17.v.2021, Umer B. Farook; 4♀, Mujagund, 34°08'11"N, 74°42'15"E, 1589m, 13.v.2021, Umer B. Farook; 4♀, Gulabagh, 34°10'52"N, 74°49'18"E, 1612m, 8.v.2021, Umer B. Farook. **Ganderbal:** 10♀ 1♂, Wakura, 34°13'19"N, 74°41'41"E, 1630m, 02.vii.2020, Umer B. Farook; 7♀, FoF, Benhama, 34°16'43"N, 74°46'37"E, 1757m, 4.vii.2020, Umer B. Farook; 6♀, Gutlibagh, 34°16'33"N, 74°49'39"E, 1778m, 6.vii.2020, Umer B. Farook; 9♀, Eco-park Manigam, 34°16'40"N, 74°48'41"E, 1668m, 12.vii.2020, Umer B. Farook; 14♀, Kijpora, 34°16'24"N, 74°53'05"E, 1770m, 7.vii.2020, Umer B. Farook; 2♀, Sonamarg, 34°18'08"N, 75°17'21"E, 2669m, 15.vii.2020, Umer B. Farook; 6♀, Kangan, 34°15'56"N, 74°54'09"E, 1811m, 18.vii.2020, Umer B. Farook. **Baramulla:** 11♀, FoA wadura, 34°20'51"N, 74°24'12"E, 1585M, 01.vi.2020, Umer B. Farook; 10♀, Hadipora, 34°17'31"N, 74°24'07"E, 1588m, 03.vi.2020, Umer B. Farook; 10♀, Achabal, 34°16'21"N, 74°24'11"E, 1583m, 05.vii.2020, Umer B. Farook; 3♀, Delina, 34°14'20"N, 74°25'22"E, 1592m, 07.vi.2020, Umer B. Farook; 10♀, Pattan, 34°09'25"N, 74°33'19"E, 1599m, 11.vi.2020, Umer B. Farook. **Bandipora:** 4♀, Ajas,

34°19'56"N, 74°40'24"E, 1558m, 15.vi.2020, Umer B. Farook; 6♀, Wullar vintage park, 34° 21'49"N, 74°39'26"E, 1599m, 17.vi.2020, Umer B. Farook; 11♀, Bandipora Nishat park, 34°24'51"N, 74°38'36"E, 1597m, 18.vi.2020, Umer B. Farook; 5♀, Naidkhai, 34°13'54"N, 74°34'09"E, 1581m, 21.vi.2020, Umer B. Farook; 7♀, Vijpura, 34°16'39"N, 74°35'53"E, 1583m, 25.vi.2020, Umer B. Farook. **Shopian:** 4♀, Pinjoora, 34°43'47"N, 74°51'26"E, 1989m, 01.vii.2021, Umer B. Farook; 5♀, Imaam sahib, 34°44'32"N, 74°54'45"E, 1882m, 03-vii.2021, Umer B. Farook; 4♀, Hirpora, 34°41'02"N, 74°47'35"E, 2269m, 08.vii.2021, Umer B. Farook; 5♀, Balpora , 33°55'37.12.3"N, 74°39'15.6"E, 2100m, 11.vii.2021, Umer B. Farook; 5♀, 1♂, Hermain, 34°42'26"N, 74°56'04"E, 1849m, 15.vii.2021. Kupwara: 5♀, Chogul, 34°24'14"N, 74°19'31"E, 1593m, 02.vi.2020, Umer B. Farook; 7♀, Vilgam, 34°28'21"N, 74°08'48"E, 17884m, 04.vi.2020, Umer B. Farook; 8♀, Nutnussa, 34°26'50"N, 74°17'59"E, 1592m, 06.vi.2020, Umer B. Farook; 7♀, 2♂, Langate, 34°18'27"N, 74°17'59"E, 1710m, 09.vi.2020.

Kargil: 7♀, Research station kargil, 34°32'19"N, 76° 09'04"E, 2700m, 02.viii.2020, Umer B. Farook; 12♀ 2♂, KVK Kargil, 34°31'13"N, 76° 08'35"E, 2670m, 04. viii.2020, Umer B. Farook; 12♀, Minjee, 34°29'10"N, 76° 06'06"E, 2676m, 06. viii.2020, Umer B. Farook; 6♀, Sankoo, 34°17'31"N, 75° 57'39"E, 2630m, 8.viii.2020, Umer B. Farook. **Leh:** 7♀, Kvk Leh (HAMARI), 33°58'30"N, 77°41'56"E, 3304m, 12.vii.2021, Umer B. Farook; 12♀, Leh park, 34°08'47"N, 77°34'51"E, 3385m, 13.vii.2021, Umer B. Farook; 12♀, Kuzey chuchot, 34°05'37"N, 77°35'19"E, 3224m, 14.vii.2021, Umer B. Farook; 8♀, Shey, 34°04'08"N, 77°37'56"E, 3237m, 14.vii.2021, Umer B. Farook.

Description of male, female characters and morphometry of *Xylocopa* (*Xylocopa*) *valga* Gerstaecker, 1872 is presented in Table 4, 5 & 6, respectively.

Table 4: Description of male characters of *Xylocopa (Xylocopa) valga* (Gerstaecker, 1872)

Body Description	Male (Plate 8)
Pubesence	Integument black, entire body with brownish black hairs
Head	Face evenly and deeply punctate in first-degree density. Clypeus with an elevated median unpunctate band. Tentorial pits weak, round. Apical emargination of labrum deep. Mandibles smooth; basal triangular area poorly defined; inner tooth as broad as the outer. Genae each with 3 to 4 punctures near the posterior margin. Inter-ocellar distance a little longer than ocello-ocular distance. Inter-antennal distance shorter than antenno-ocular distance.
Mesosoma	Knee-caps extending to basal 3/4 of tibial length; upper projection flat, thin, broadly rounded; lower projection sharp, thick.
Metasoma	Abdominal tergites finely and shallowly punctate, with a narrow median unpunctate band; epipygium apically emarginated.
Genetalia	Genital capsule broader; inner lobe of gonocoxite well developed; gonostylus broad with setae on its apex, penis valve elongated & broader apically and divergent. Median lobe of gonostylus absent

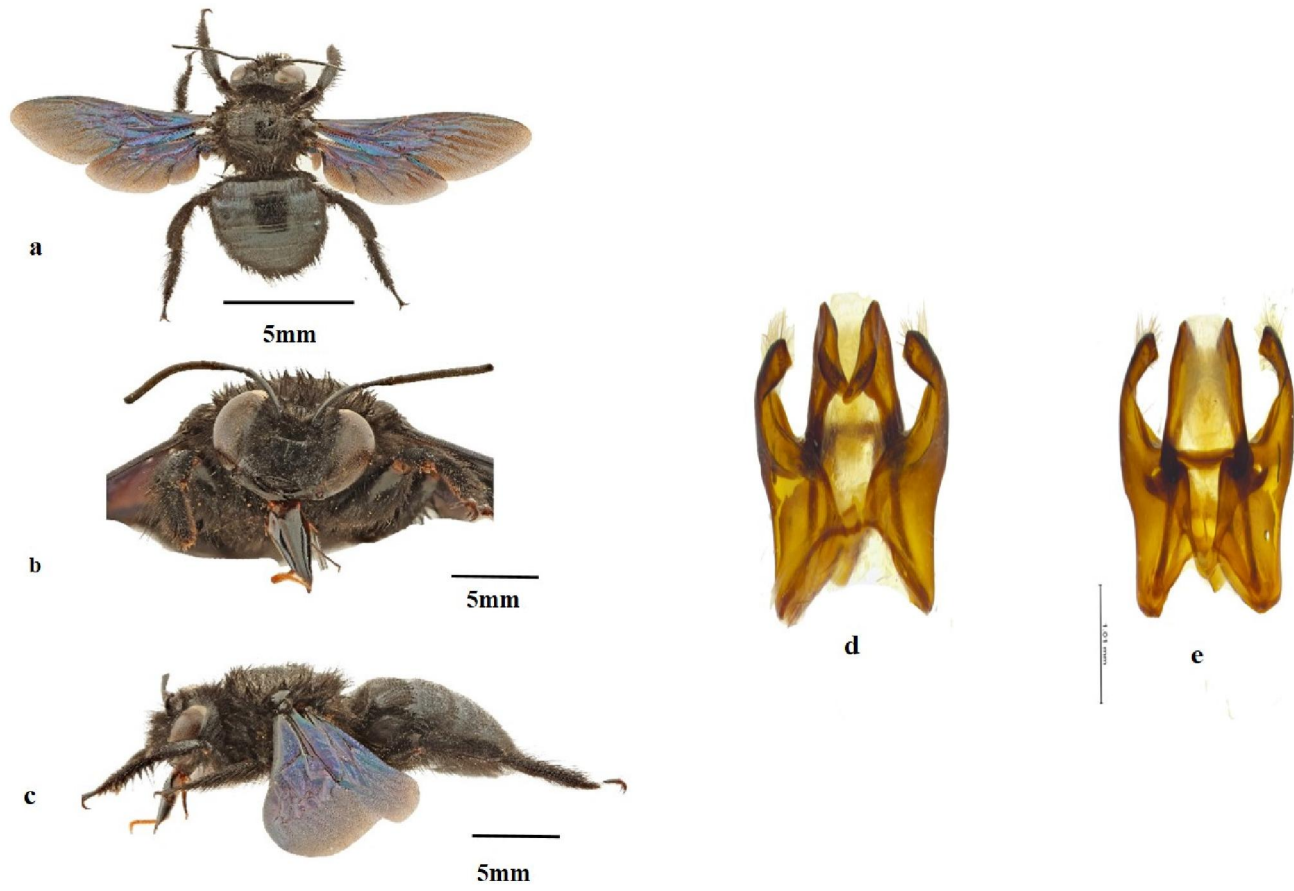


Plate 8: *Xylocopa (Xylocopa) valga* Gerstaecker, (♂)
a. Dorsal view b. frontal view c. lateral view d-e. genitalia; d. dorsal view e. ventral view

Table 5: Description of female characters of *Xylocopa (Xylocopa) valga* (Gerstaecker, 1872)

Body Description	Female (Plate 9)
Pubesence	Integument black, Mesosoma covered dorsally with black hairs
Head	Tentorial pits elongate. Mandibles with emarginated inner margin and truncate inner teeth; intermediate and outer teeth sharply pointed. Genae usually unpunctate. Postgenae and vertex punctate in second-degree density.
Mesosoma	Basitibial plate with 5–6 longitudinal series of denticles, Venter of posterior femora shallowly and evenly punctate in third-degree density. Knee-caps extending to basal ½ of tibial length. Inner surface of posterior metatarsi with a smooth, elevated, triangular area. Inner teeth of posterior claws much shorter than -the outer.
Metasoma	Abdominal tergites except the epipygium with fine, shallow and irregularly distributed punctures of third-degree density, with a distinct median unpunctate band. Hypopygium with a median keel near the apex.

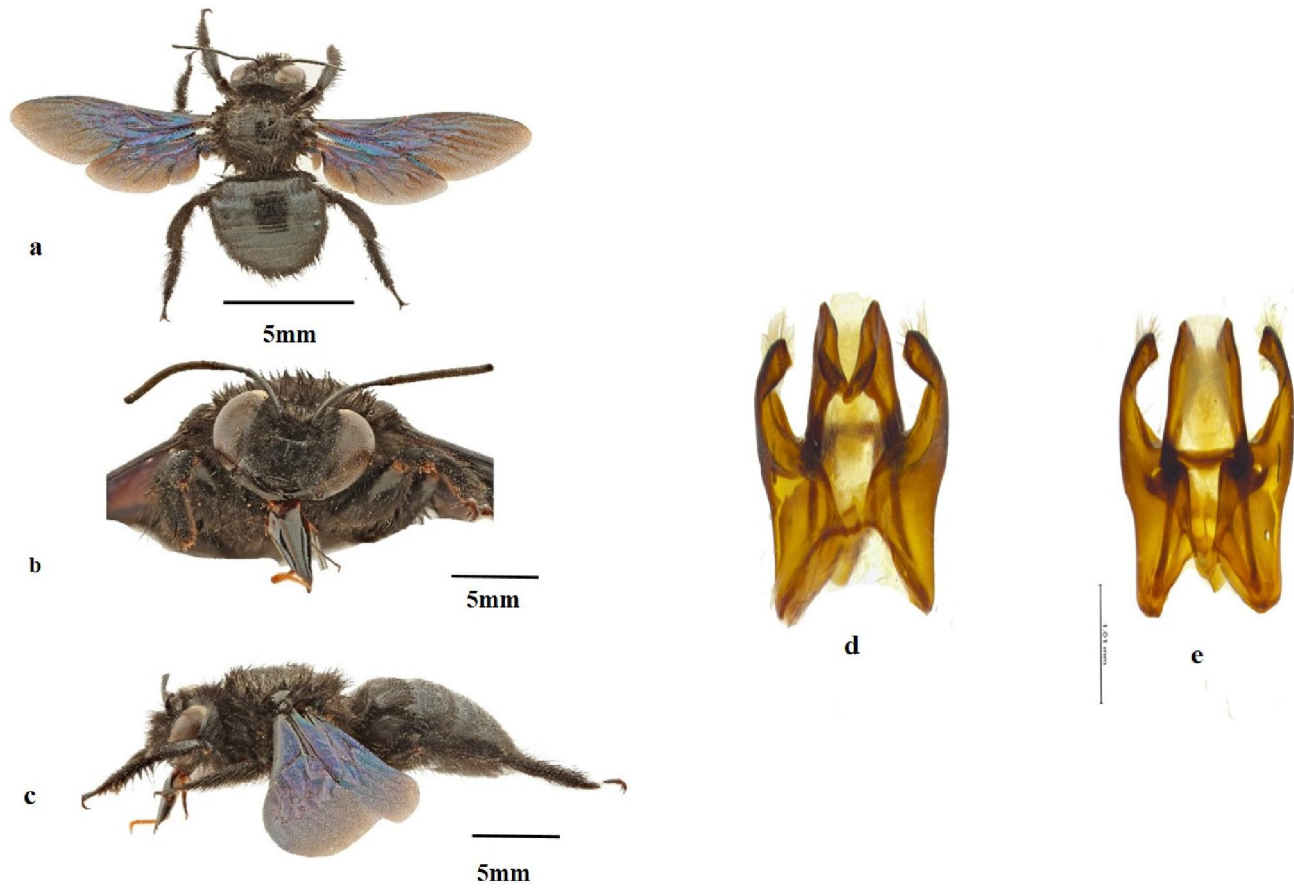


Plate 8: *Xylocopa (Xylocopa) valga* Gerstaecker, (♂)
b. Dorsal view b. frontal view c. lateral view d-e. genitalia; d. dorsal view e. ventral view

Table 6: Morphometry of *Xylocopa (Xylocopa) valga* (Gerstaecker, 1872) (N=10)

Parameters	Male	Female
	Mean \pm S.D(mm)	Mean \pm S.D(mm)
Total body length	28.20 \pm 2.08	32.85 \pm 2.48
Length of head	5.88 \pm 0.68	6.39 \pm 1.08
Width of head	7.54 \pm 1.16	8.86 \pm 1.01
Length of scape	2.54 \pm 0.49	3.17 \pm 0.42
Width of scape	.35 \pm 0.09	0.38 \pm 0.07
Length of pedicel	0.24 \pm 0.03	0.26 \pm 0.06
Width of pedicel	0.31 \pm 0.08	0.38 \pm 0.06
Length of F1	0.89 \pm 0.33	1.30 \pm 0.16
Width of F1	0.27 \pm 0.07	0.30 \pm 0.06
Length of F2-F10 or F11	3.76 \pm 0.79	4.60 \pm 0.07
Inter antennal distance	0.96 \pm 0.39	0.95 \pm 0.30
Antenno-ocellar/ Alveolocellar distance	0.65 \pm 0.30	0.60 \pm 0.32
Length of mandible	2.20 \pm 0.43	2.67 \pm 0.66
Total tongue Length	7.96 \pm 2.83	11.51 \pm 0.64
Length of labial palpi	3.80 \pm 1.52	5.20 \pm 0.44
Length of clypeus	1.84 \pm 0.51	2.42 \pm 0.07
Width of clypeus	2.95 \pm 0.70	3.71 \pm 1.21
Clypeoantennal distance	0.92 \pm 0.66	0.47 \pm 0.10
Width of eye	2.14 \pm 0.71	1.71 \pm 0.24

Length of Mesosoma	8.56±3.18	9.12±5.04
Width of Mesosoma	9.63±1.17	9.89±1.71
Length of Forewing	20.98±5.45	26.98± 1.60
Length of Hindwing	13.30±2.95	16.66± 0.44
Length of 1st sub marginal cell	3.56±1.29	5.44±0.85
Length of 2nd sub marginal cell	2.23±0.61	2.38±0.59
Length of 3rd sub marginal cell	2.96±0.88	4.31±0.88
Length of fore tibia	3.61±0.65	4.38± 0.45
Length of fore basitarsi	3.74±1.32	4.73± 0.63
Length of hind tibia	5.06±1.89	6.27± 0.21
Length of hind basitarsi	5.37±1.46	6.32± 0.22
Length of metasoma	12.88±2.70	16.52± 1.68
Width of metasoma	11.00±1.24	15.41±1.20
I metasomal segment length	2.24±0.79	3.12±0.28
II metasomal segment length	2.91±1.33	3.64±0.40

Remarks: *Xylocopa valga* in Kashmir valley has been misidentified as *Xylocopa violacea* as both the species are very much similar in terms of colour and size. The males are used to separate the two as in case of *X. valga* the antenna is completely black without any characteristic curve while in case of *X. violacea* the 11-12 flagellum are orange with a characteristic curve. The females of the two can be distinguished under stereoscopic microscope based on the number of rows on spines on the hind tibia; *X. valga* has more than four while *X. violacea* has only two rows of spines.

4.4 Subgenus *Ctenoxylocopa* Michener, 1938

4.4.1 *Xylocopa (Ctenoxylocopa) fenestrata* (Fabricius, 1798) (Plate 10,11)

Apis fenestrata Fabricius, 1798

Xylocopa lunata Klug, 1807

Xylocopa indica Klug, 1807

Xylocopa serripes Burmeister, 1876

Xylocopa gardineri Cameron, 1902

Xylocopa serripes_homonym Hedicke, 1938

Xylocopa hedickae Maa, 1940

Xylocopa bombayensis Maa, 1954

Xylocopa (Ctenoxylocopa) fenestrata mauritii Maa, 1970

4.4.2 Material examined

INDIA: **Jammu:** 7♀, 2♂, chattha campus: 32°39'13"N, 74°48'12"E, 267m, 1.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 6♀, R.S. Pura, 32°36'35"N 74°44'15"E, 273m, 2.iv.2021, Umer B. Farook & Ishfaq Ahmad Bhat; 11♀, 4♂ Bantalab, 32°46'57"N, 74°49'35"E, 380m, 3.iv.2021, Umer B. Farook; 9♀, 3♂, Mansar, 32°41'33"N 75°08'55"E, 663m, 6.iv.2021, Umer Bin Farook, Gulzar Ah, Ishfaq Ahmad Bhat; 9♀, Suransar, 32°46'00"N 75°02'39"E, 606m, 6.iv.2021, Umer Bin Farook, Gulzar Ah, Ishfaq Ahmad Bhat. **Kathua:** 3♀, KVK Kathua, 32°22'46"N 75°30'17"E ,333m, 8.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 10♀, 3♂, KK Birla public park, 32°23'42"N 75°30'52"E, 364m, 8.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 1♀, Barnoti, 32°25'22"N 75°26'44"E, 346m, 9.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 11♀, 4♂, Rakh lachipura, 32°24'20"N 75°28'06"E, 348m, 9.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat. **Doda:** 3♀, 1♂, Pul Doda, 33°08'06"N 75°33'11"E, 1010m, 12.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 3♀, 1♂, Main Doda,

33°08'33"N75°33'03"E, 1102m, 12.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 0♀, 0♂, KVK, Doda, 32°58'59"N 75°43'03"E, 1607m, 13.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 0♀, 0♂, sartingle, 32°56'57"N 75°43'44"E, 1765m, 13.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat. **Ramban:** 3♀, Batote, 33°07'19"N 75°19'15", 1546m, 06.v.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 7♀, 1♂, Ramsoo, 33°20'10"N 75°11'35"E, 1189m, 06.v.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 0♀, 0♂, Patnitop, 33°05'22"N 75°19'37"E, 2031m, 03.v.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 6♀, ramban, 33°14'28"N 75°14'15"E, 721m, 06.v.2021, Umer. B. Farook & Ishfaq Ahmad bhat. **Rajouri:** 11♀, 3♂, KVK Rajouri, 33°22'33"N74°17'18"E, 913m, 01.v.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 0♀, 0♂, Budhal, 33°22'33"N 74°38'49"E, 1785m, 03.v.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 10♀, 3♂, Saj thanamandi, 33°27'24"N 74°19'49"E, 1122m, 02.v.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 7♀, 1♂, Badhori, shahdara sharif, 33°33'04"N 74°20'23"E, 1621m, 02.v.2021, Umer. B. Farook & Ishfaq Ahmad bhat. **Poonch:** 9♀, 2♂, KVK Poonch, 33°46'00"N 74°06'40"E, 1004m, 25.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 8♀, Lassana, 33°41'45"N 74°14'07"E, 1248m, 26.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 2♀, Dundak, 33°40'55"N 74°14'53"E, 1335m, 26.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 0♀, 0♂, Naka manjheri, 33°36'02"N 74°14'47"E, 1242m, 27.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat.

Description of male, female characters and morphometry of (*Ctenoxylocopa fenestrata* (Fabricius, 1798) is presented in Table 7, 8 & 9, respectively.

Table 7: Description of male characters of *Xylocopa (Ctenoxylocopa) fenestrata* (Fabricius, 1798)

Body Description	Male (Plate 10)
Pubescence	Dominantly black with pale hairs on face and mesosoma; ventral surface of hind femur with long black sub-plumose setae, anterior surface of hind tibia uniformly setose, ventral surface with long dense setae.
Head	Integument black, head narrower than thorax including tegulae; ocelli ordinary size, median ocellus rounded; face very deeply and evenly punctuate; less punctuate on interspaces between lateral ocelli and inner orbits; tentorial pits shallow, elongate; genae unpunctate, mandibles bidentate basally with roundish punctures,
Mesosoma	Triangular area of propodeum small; scutellum and postscutellum running gradually into the succeeding segments; posterior portion of scutellum depressed at the same slope with postscutellum and propodeum; lateral portions of mesonotum with white hairs; scutellum less punctuate; hind femur in ventral view twice as long as wide,
Metasoma	Spiracular tubercles on T3 with teeth-like, strongly projecting outwards; T1-T5 with sparsely fine and shallow punctures, T6-T7 are densely punctate with narrow median impunctate band; T7 (epipygium) distally depressed, apically margin straight or medially truncate, laterally with a strong triangular projection which is dorsally punctate and ventrally unpunctate; hypopygium medially depressed without median keel or impunctate band;
Genitalia	Genital capsule wider than long; basal and apical portion almost equal in breadth; gonostylus at apex of gonocoxite slender; gonostylus without any projection; no setae on apex of gonostylus; median lobe on gonostylus absent; inner margin of gonocoxite weakly parallel; penis entirely membranous; penis valve slender and parallel; Lateral edge on genital capsule absent; no hairs on base of the penis valve.

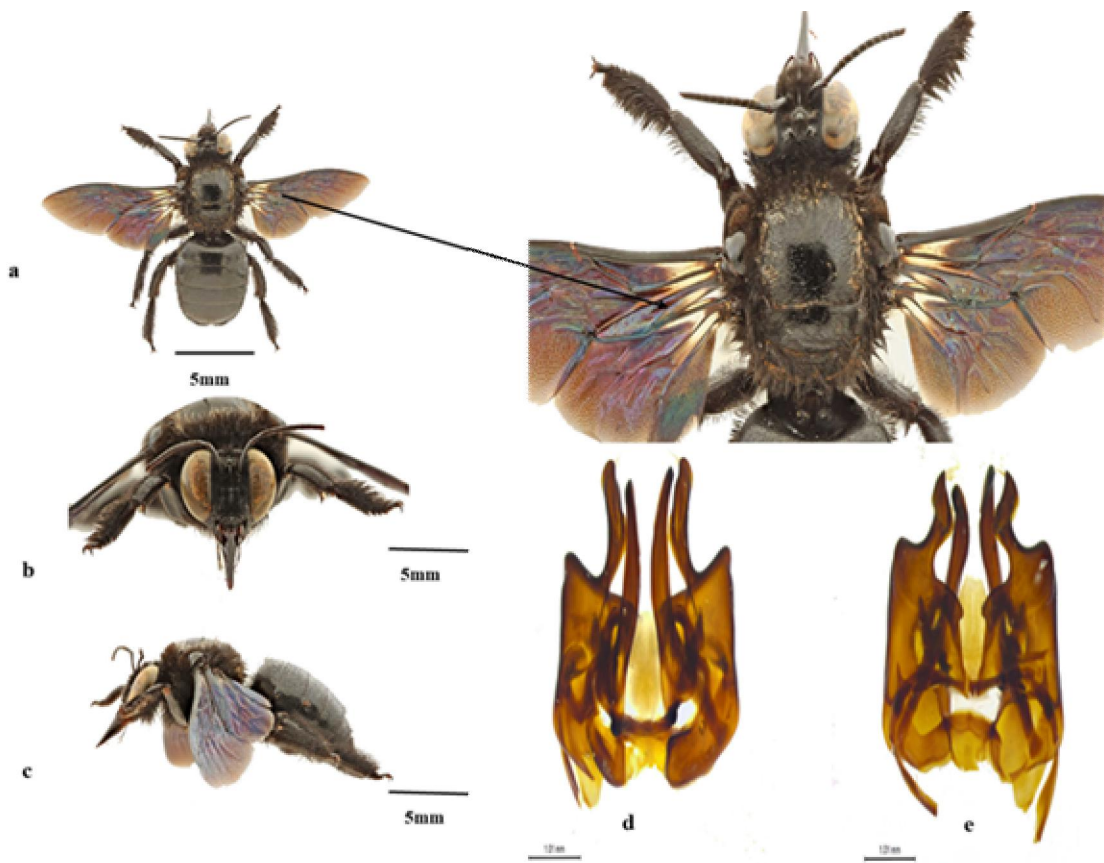


Plate 10: *Xylocopa (Ctenoxylocopa) fenestrata* (♂)

- a. Dorsal view b. frontal view c. lateral view d-e. genitalia; d. dorsal view e. ventral view

Table 8: Description of female characters of *Xylocopa (Ctenoxylocopa) fenestrata* (Fabricius, 1798)

Body Description	Female (Plate 11)
Pubescence	Face usually entirely black hairs, rarely with silvery soft hairs; clypeus with purely black setose, hind legs with dense long and sooty black colour <i>pubescens</i> ; lateral margins of the metasoma towards its apex fringed with black <i>pubescens</i> ; S3-S5 black setose, at most with pale setae on lateral portions.
Head	As wide as the mesosoma, strongly and closely punctured; interocellar distance and ocellorbital distance subequal, interspace of posterior ocelli weakly depressed
Mesosoma	Mesonotum with three obscure, parallel, longitudinally impressed lines; disc of the mesonotum impunctate; scutellum running gradually into postscutellum, only separated by a suture; hind femur sharply edged along full length of posterior margin; basitibial plate on hind tibia with two rows of dentiform spine like process parallally extended upto $\frac{3}{4}$ of tibial length and apically bifurcated; wings dark brown to black, with a bright violet iridescence towards their base, changing to an tint at their apical margins, not clear hyaline at extreme bases
Metasoma	Anterior portion of the T1 with unpunctate area and median line; pygidial plate with medial groove widest at intermediate section, often with extra minor spines at base; submedian process of epipygium narrow projecting outwards and parallel to each other; hypopygium basally with a broad median unpunctate band and apically with strong median keel; lateral spines of pygidial plate conical, not lying on oblique planes; epipygium medially furrowed.

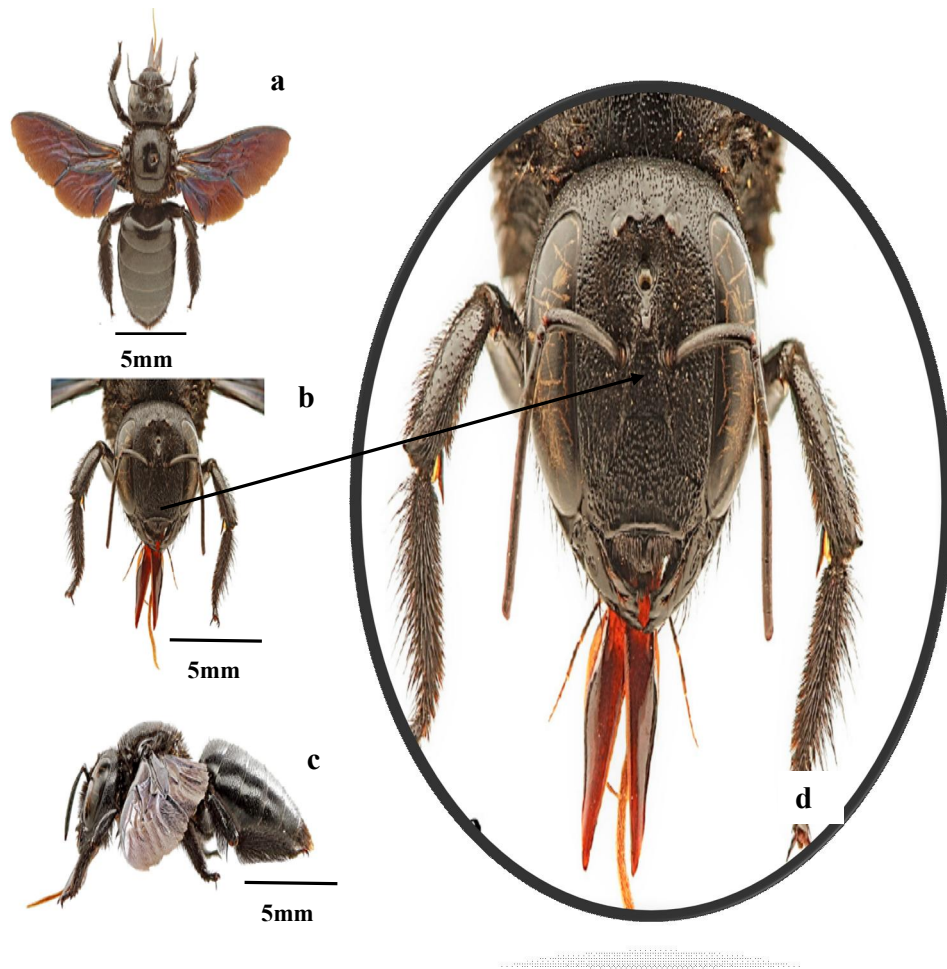


Plate 11: *Xylocopa (Ctenoxylocopa) fenestrata* (♀)

a. Dorsal view **b.** frontal view **c.** lateral view **d.** head enlarged view **e.** face close up view

Table 9: Morphometry of *Xylocopa (Ctenoxylocopa) fenestrata* (Fabricius, 1798). (N=10)

Parameters	Male	Female
	Mean \pm S.D(mm)	Mean \pm S.D(mm)
Total body length	22.82 \pm 2.26	23.70 \pm 3.07
Length of head	5.15 \pm 0.40	6.24 \pm 1.00
Width of head	7.03 \pm 0.72	7.36 \pm 0.91
Length of scape	2.48 \pm 0.58	2.69 \pm 0.72
Width of scape	0.31 \pm 0.06	0.33 \pm 0.05
Length of pedicel	0.22 \pm 0.01	0.27 \pm 0.06
Width of pedicel	0.26 \pm 0.03	0.29 \pm 0.04
Length of F1	0.77 \pm 0.17	0.81 \pm 0.19
Width of F1	0.23 \pm 0.05	0.28 \pm 0.07
Length of F2-F10 or F11	3.91 \pm 0.52	3.54 \pm 0.41
Inter antennal distance	0.93 \pm 0.27	1.12 \pm 0.40
Antenno-ocellar/ Alveolocellar distance	0.57 \pm 0.12	0.70 \pm 0.25
Length of mandible	2.22 \pm 0.62	2.44 \pm 0.68
Total tongue Length	7.65 \pm 1.91	7.49 \pm 2.03
Length of labial palpi	3.83 \pm 0.95	3.66 \pm 1.28
Length of clypeus	1.92 \pm 0.37	1.83 \pm 0.48
Width of clypeus	2.76 \pm 0.71	3.16 \pm 0.82
Clypeoantennal distance	0.64 \pm 0.10	0.63 \pm 0.10
Width of eye	2.09 \pm 0.12	1.71 \pm 0.24
Length of Mesosoma	7.25 \pm 0.76,	6.87 \pm 0.28
Width of Mesosoma	9.14 \pm 0.69	8.94 \pm 0.73
Length of Forewing	18.53 \pm 2.14	19.17 \pm 2.77
Length of Hindwing	12.13 \pm 1.31	12.51 \pm 1.73
Length of 1st sub marginal cell	2.78 \pm 0.10,	2.89 \pm 0.18
Length of 2nd sub marginal cell	1.90 \pm 0.25	2.03 \pm 0.32
Length of 3rd sub marginal cell	2.75 \pm 0.51	2.80 \pm 0.62
Length of fore tibia	3.81 \pm 0.75	3.69 \pm 0.77
Length of fore basitarsi	3.23 \pm 0.95	3.49 \pm 0.92
Length of hind tibia	4.86 \pm 0.28	4.34 \pm 0.82
Length of hind basitarsi	4.71 \pm 0.25	4.77 \pm 0.42
Length of metasoma	12.06 \pm 2.66	12.76 \pm 2.50
Width of metasoma	9.52 \pm 0.86	9.55 \pm 0.94
I metasomal segment length	1.61 \pm 0.31	1.72 \pm 0.35
II metasomal segment length	2.31 \pm 0.17	2.32 \pm 0.32

Remarks: Maa (1970) has provided a revision of the subgenus *Ctenoxylocopa*. Male genitalia of *X. fenestrata* closely resembles *X. basalis*, but *X. fenestrata* can be differentiated from all other *Ctenoxylocopa* by the posterior margin of T7 with a pair of posterolateral spine like denticles. Maa (1970) differentiated the *X. fenestrata* into two subspecies *X. fenestrata fenestrata* and *X. fenestrata mauritii*.

4.5 Subgenus *Koptortosoma* Gribodo, 1894

4.5.1 *Xylocopa (Koptortosoma) pubescens* (Spinola, 1838) (Plate 12, 13)

Xylocopa aestuans varrubida Gribodo, 1884

Xylocopa aestuans bengasinensis Warncke, 1976

4.5.2 Material examined

INDIA: **Jammu** 9♀, 2♂, chattha campus: 32°39'13"N, 74°48'12"E, 267m, 1.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 6♀, R.S. Pura, 32°36'35"N 74°44'15"E, 273m, 2.iv.2021, Umer B. Farook & Ishfaq Ahmad Bhat; 06♀, 1♂ Bantalab, 32°46'57"N, 74°49'35"E, 380m, 3.iv.2021, Umer B. Farook; 9♀, Mansar, 32°41'33"N 75°08'55"E, 663m, 6.iv.2021, Umer Bin Farook, Gulzar Ah, Ishfaq Ahmad Bhat; 0♀, Suransar, 32°46'00"N 75°02'39"E, 606m, 6.iv.2021, Umer Bin Farook, Gulzar Ah, Ishfaq Ahmad Bhat. **Kathua:** 2♀, KVK Kathua, 32°22'46"N 75°30'17"E, 333m, 8.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 9♀, 3♂, KK Birla public park, 32°23'42"N 75°30'52"E, 364m, 8.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 5♀, Barnoti, 32°25'22"N 75°26'44"E, 346m, 9.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 1♀, Rakh lachipura, 32°24'20"N 75°28'06"E, 348m, 9.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat. **Doda:** 0♀, Pul Doda, 33°08'06"N 75°33'11"E, 1010m, 12.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 0♀, 0♂, Main Doda, 33°08'33"N 75°33'03"E, 1102m, 12.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 0♀, 0♂, KVK, Doda, 32°58'59"N 75°43'03"E, 1607m, 13.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 0♀, 0♂, sartingle, 32°56'57"N 75°43'44"E, 1765m, 13.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat. **Ramban:** 2♀, Batote, 33°07'19"N 75°19'15",

1546m, 06.v.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 2♀, Ramsoo, 33°20'10"N 75°11'35"E, 1189m, 06.v.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 0♀, 0♂, Patnitop, 33°05'22"N 75°19'37"E, 2031m, 03.v.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 0♀, ramban, 33°14'28"N 75°14'15"E, 721m, 06.v.2021, Umer. B. Farook & Ishfaq Ahmad bhat. **Rajouri:** 0♀, 0♂, KVK Rajouri, 33°22'33"N 74°17'18"E, 913m, 01.v.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 0♀, 0♂, Budhal, 33°22'33"N 74°38'49"E, 1785m, 03.v.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 0♀, 0♂, Saj thanamandi, 33°27'24"N 74°19'49"E, 1122m, 02.v.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 0♀, 0♂, Badhori, shahdara sharif, 33°33'04"N 74°20'23"E, 1621m, 02.v.2021, Umer. B. Farook & Ishfaq Ahmad bhat. **Poonch:** 13♀, 2♂, KVK Poonch, 33°46'00"N 74°06'40"E, 1004m, 25.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 3♀, Lassana, 33°41'45"N 74°14'07"E, 1248m, 26.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 1♀, Dundak, 33°40'55"N 74°14'53"E, 1335m, 26.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 3♀, 1♂, Naka manjheri, 33°36'02"N 74°14'47"E, 1242m, 27.iv.2021, Umer. B. Farook & Ishfaq Ahmad bhat.

Description of male, female characters and morphometry of *Xylocopa (Koptortosoma) pubescens* (Spinola, 1838) is presented in Table 10, 11 & 12, respectively.

Table 10: Description of male characters of *Xylocopa (Koptortosoma) pubescens* (Spinola, 1838)

Body Description	Male (Plate 12)
Pubescence	Dominantly yellow, generally short, dense and evenly distributed; concealing most of the surface on head, thorax and T1, anterior surface of T1 with pale <i>pubescens</i> ; sparser on remaining segments; longest on scutellum and apex of the last metasomal segment, short on T2- T6, but longer, denser and more erect on T1; base of hind tibia with more yellow hairs and apical half with band of thick black hairs surrounded by pale yellow hairs,
Head	Head surface almost flat, frons and clypeus not elevated, frontal keel short and sharp; clypeus evenly densely punctate, anterior margin emarginated; upper orbital distance greater than lower, inner orbits weakly divergent at their upper extremities; face without pale markings; first three antennal segments with dark yellow band, from IV to VII segment yellow to orange, remaining segments are dark brown; last antennal segment dorsoventrally compressed towards apical portion and ventrally with small elongated depression or pit like structure
Mesosoma	Surface of mesoscutum on level with that of scutellum; propodeum longitudinally sulcate, surface evenly punctate, punctures smaller than interspaces; tegulae outer margin convex, rounded behind the posterolateral third, impunctate glabrous and shining; wings are subhyaline; forewing darker brown at costal margin with light purple iridescence towards apex
Metasoma	Relatively short, oval, moderately convex above; no median longitudinal carina or distinct impunctate median line; dorsal surface slightly shining; posterior margin of T2-T5 impunctate; anterior portion of T1 sub acute, except lateral edges, deeply hollowed out, with acarinarium. T7 truncated, armed with a short, robust, triangular spine on either side of emargination; sternites less densely punctate as compared with the tergites; S1– S5 with distinct, polished, median longitudinal stripe, widest basally, S6 with strong
Genitalia	Genital capsule almost as long as wide; inner lobe of gonocoxite well developed; medial projection of gonostylus short; medial lobe of ventral apical plate with few short hairs; gonostylus with dense patch of setae on its apex and base; penis valve elongated apically and convergent.

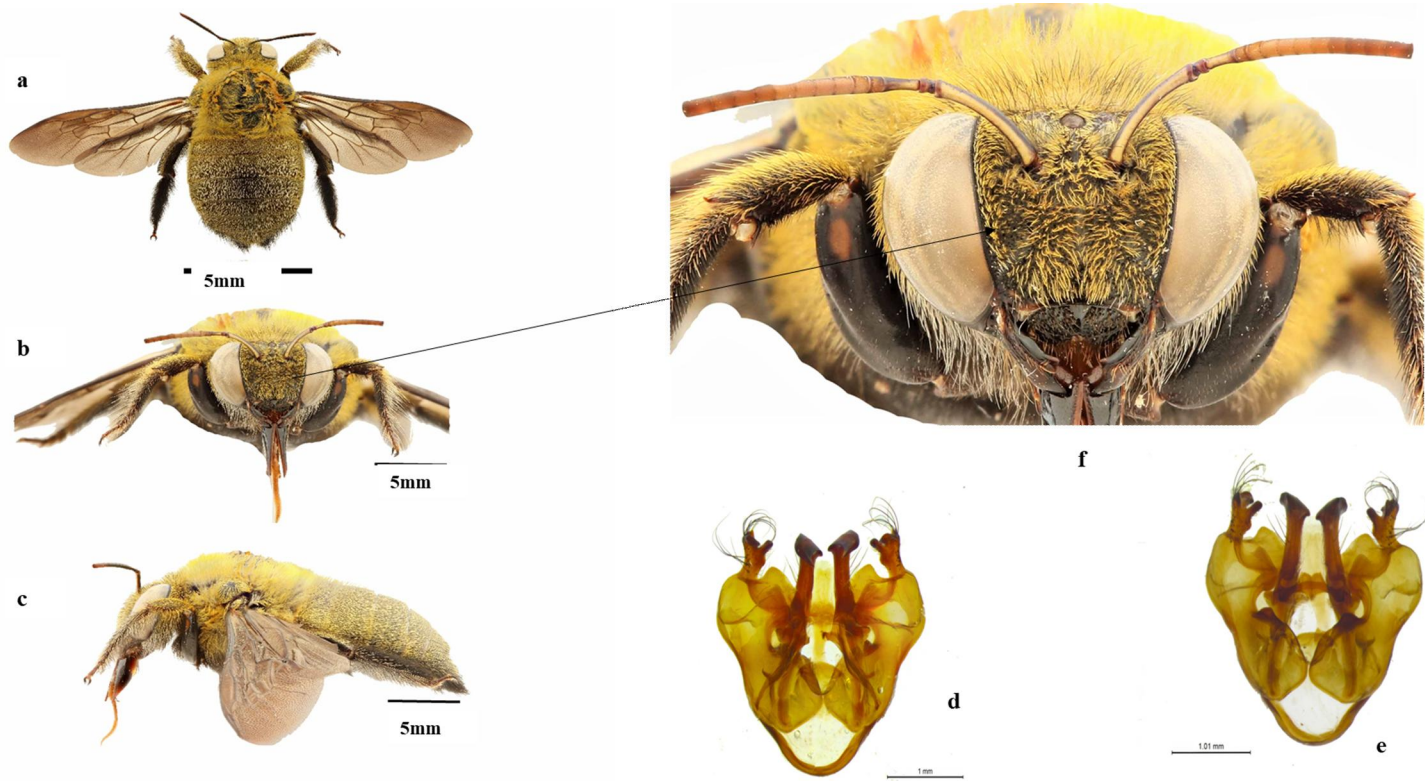


Plate 12: *Xylocopa (Koptortosoma) pubescens*, (♂)

a. Dorsal view **b.** frontal view **c.** lateral view **d-e.** genitalia; **d.** dorsal view **e.** ventral view **f.** face close up view

Table 11: Description of female characters of *Xylocopa (Koptortosoma) pubescens* (Spinola, 1838)

Body Description	Female (Plate 13)
Pubescence	Face with mixture of black and pale plumose hairs. Gena, occiput, vertex covered with black <i>pubescens</i> , yellow hairs absent; yellow <i>pubescens</i> on thoracic dorsum lighter, postscutellum with few scattered yellow hairs, first abdominal tergite without yellow hairs
Head	Head slightly broader than long, subcircular in outline, the occipital area higher and more strongly convex in frontal view; orbit without groove along outer margin, more densely punctate than postgena; supraclypeal region and clypeus very flat lying on same slope or slightly elevated near their junction; clypeus evenly densely punctate without indication of a median impunctate line; flagellar segments of antenna shorter, III segment more nearly parallel-sided, 2 times as long as its width at apex and slightly longer than IV+V; mandibles are short and stout or robust with deeply sulcate inner margin, basally with strong depression and having 10 to 15 punctures
Mesosoma	Disc of the mesonotum smooth and medially unpunctate; the tips of the medially inclined decumbent yellow hairs on either side of it hardly meeting. Median mesoscutal line feebly, less sharply, impressed; wings dark fuscous with a purple effluence; distal side of third submarginal cell of fore wing evenly convex, the bend situated exactly mid-way its course;
Metasoma	T1 and T2 more densely punctate sometimes with scattered yellow hairs which never form a patch, black <i>pubescens</i> of gastral tergites short and sparse.

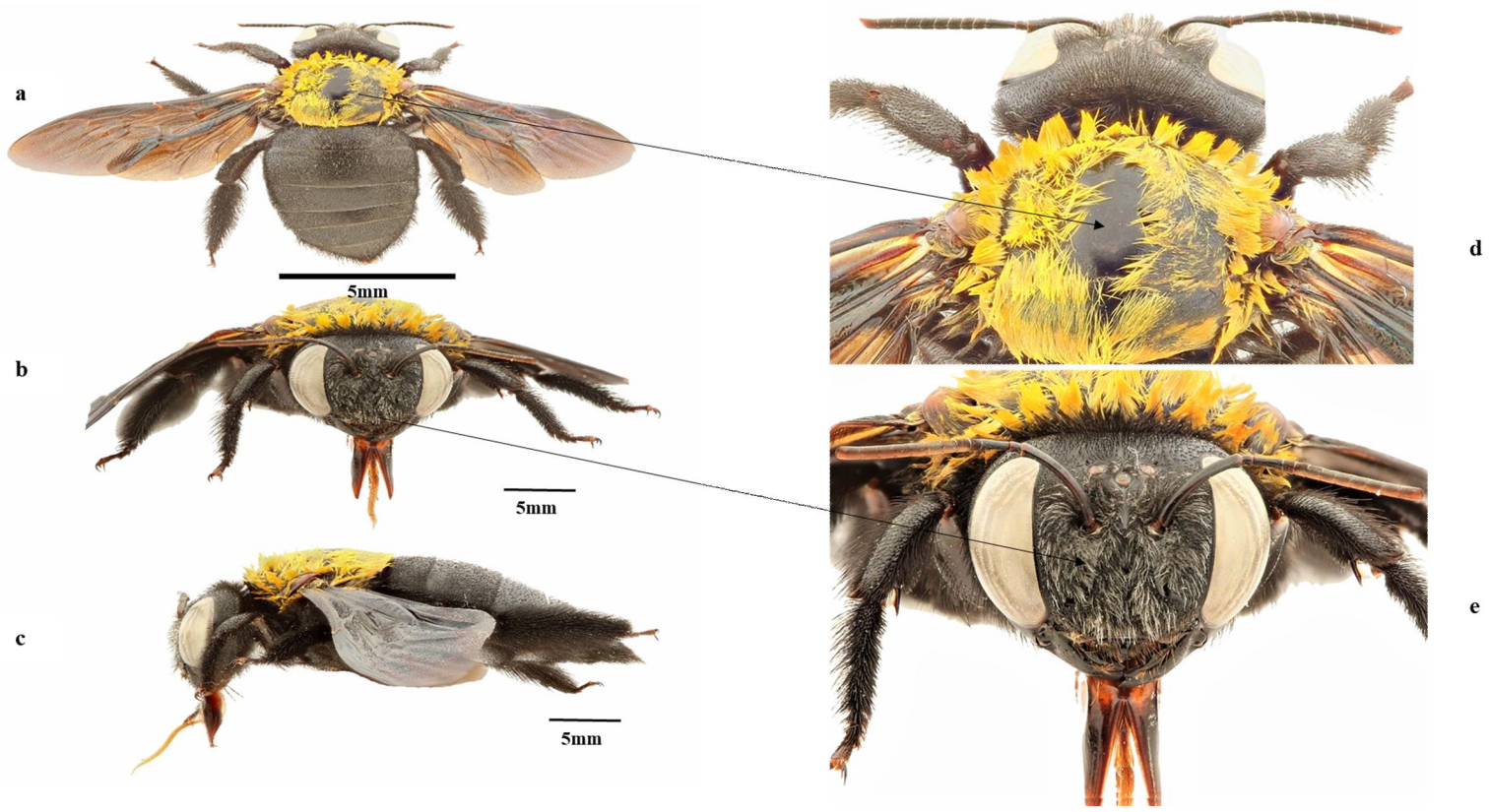


Plate 13: *Xylocopa (Koptortosoma) pubescens* (♀)
a. Dorsal view **b.** frontal view **c.** lateral view **d.** thorax close up view **e.** face close up view

Table 12: Morphometry of *Xylocopa (Koptortosoma) pubescens* (Spinola, 1838) (N=10)

Parameters	Male	Female
	Mean \pm S.D (mm)	Mean \pm S.D (mm)
Total body length	17.67 \pm 0.15	21.70 \pm 0.61
Length of head	3.82 \pm 0.06	5.62 \pm 0.12
Width of head	5.77 \pm 0.08	7.33 \pm 0.04
Length of scape	1.75 \pm 0.03	2.57 \pm 0.01
Width of scape	0.45 \pm 0.21	0.28 \pm 0.03
Length of pedicel	0.28 \pm 0.01	0.29 \pm 0.03
Width of pedicel	0.22 \pm 0.01	0.25 \pm 0.02
Length of F1	0.34 \pm 0.21	0.67 \pm 0.03
Width of F1	0.22 \pm 0.01	0.24 \pm 0.01
Length of F2-F10 or F11	3.09 \pm 0.11	3.07 \pm 0.09
Inter antennal distance	1.00 \pm 0.03	1.07 \pm 0.02
Antenno-ocellar/ Alveolocellar distance	0.65 \pm 0.03	0.93 \pm 0.05
Length of mandible	1.67 \pm 0.01	2.30 \pm 0.09
Total tongue Length	6.18 \pm 0.02	5.44 \pm 0.03
Length of labial palpi	2.45 \pm 0.24	3.17 \pm 0.05
Length of clypeus	1.49 \pm 0.03	1.76 \pm 0.03
Width of clypeus	2.17 \pm 0.09	2.98 \pm 0.18
Clypeoantennal distance	0.66 \pm 0.03	0.70 \pm 0.02
Width of eye	1.76 \pm 0.01	1.06 \pm 0.07
Length of Mesosoma	5.52 \pm 0.09	6.23 \pm 0.03
Width of Mesosoma	8.33 \pm 0.13	8.97 \pm 0.04
Length of Forewing	16.86 \pm 0.50	18.10 \pm 0.04
Length of Hindwing	11.30 \pm 0.87	12.05 \pm 0.04
Length of 1st sub marginal cell	2.51 \pm 0.01	2.89 \pm 0.03
Length of 2nd sub marginal cell	1.81 \pm 0.01	0.74 \pm 0.04
Length of 3rd sub marginal cell	1.92 \pm 0.03	2.35 \pm 0.05
Length of fore tibia	3.06 \pm 0.11	3.86 \pm 0.77
Length of fore basitarsi	2.60 \pm 0.20	3.30 \pm 0.03
Length of hind tibia	3.92 \pm 0.05	3.80 \pm 0.01
Length of hind basitarsi	3.86 \pm 0.30	4.88 \pm 0.26
Length of metasoma	9.06 \pm 0.04	11.03 \pm 0.13
Width of metasoma	9.61 \pm 0.35	9.73 \pm 0.01
I metasomal segment length	2.14 \pm 0.34	2.24 \pm 0.03
II metasomal segment length	2.21 \pm 0.27	2.65 \pm 0.01

Remarks: This species is often confused with *X. aestuans* (Linnaeus, 1758). The name *X. aestuans* has been employed by many authors for several different species of the subgenus *Koptortosoma*. It has been clarified by Lieftinck (1964). Though apparently widespread in the northern parts of the Ethiopian region and western Asia, extending its range far eastward to Peninsular India, it is still impossible to give an accurate picture of the distribution of this bee. Females of *X. pubescens* and *X. aestuans* are difficult to separate, because some characters are shared by both the species. They can be separated by following key.

1. Female with clypeus evenly densely punctate, metasomal tergites with short, sparse *pubescens*; male without basal spine-like process on hind femur..... *X. pubescens*

- Female with median impunctate line on clypeus; metasomal tergites with long dense *pubescens*; male with basal spine-like process on hind femur..... *X. aestuans*

4.6 Subgenus *Zonohirsuta* Ma, 1938

4.6.1 *Xylocopa (Zonohirsuta) dejeanii* Lepeletier, 1841 (Plate 14, 15)

Xylocopa collaris Lepeletier, 1841;

Xylocopa dejeanii Lepeletier, 1841;

Xylocopa dejeanii Hurd and Moure 1963

4.6.2 Material examined

INDIA: **Jammu: Ramban:** 1♀, Batote, 33°07'19"N 75°19'15", 1546m, 06.v.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 2♀, 1♂, Patnitop, 33°05'22"N 75°19'37"E, 2031m, 03.v.2021, Umer. B. Farook & Ishfaq Ahmad bhat; 0♀, ramban, 33°14'28"N 75°14'15"E, 721m, 06.v.2021, Umer. B. Farook & Ishfaq Ahmad bhat. **Rajouri:** 2♀, 0 ♂, Budhal, 33°22'33"N 74°38'49"E, 1785m, 03.v.2021, Umer. B. Farook & Ishfaq Ahmad bhat.

Description of male, female characters and morphometry of *Xylocopa* (*Zonohirsuta*) *dejeanii* Lepeletier, 1841 is presented in Table 13, 14 & 15, respectively.

Table 13: Description of male characters of *Xylocopa* (*Zonohirsuta*) *dejeanii* (Lepeletier, 1841)

Body Description	Male (Plate 14)
Pubesence	clypeus, face yellow with thin yellowish brown hairs on vertex,
Head	sparsely punctate; epistomal suture not straight, slightly curved near anterior tentorial pit. Clypeus, supraclypeaus area creamy white with golden hairs
Mesosoma	pronotum, sides of the thorax anteriorly, front of the mesonotum, anterior legs and basal one or two gastral tergites ochraceous; wings subhyaline, lightly fuscous with purple effulgence.
Metasoma	Pale hairs extending to III abdominal tergite. T3 larger than other abdominal segments. Sparsely golden yellow hairs with dense tuft at last segment
Genetalia	Genital capsule oval shaped; inner lobe of gonocoxite well developed; gonostylus with tuft of setae on its apex , penis valve elongated apically and divergent.

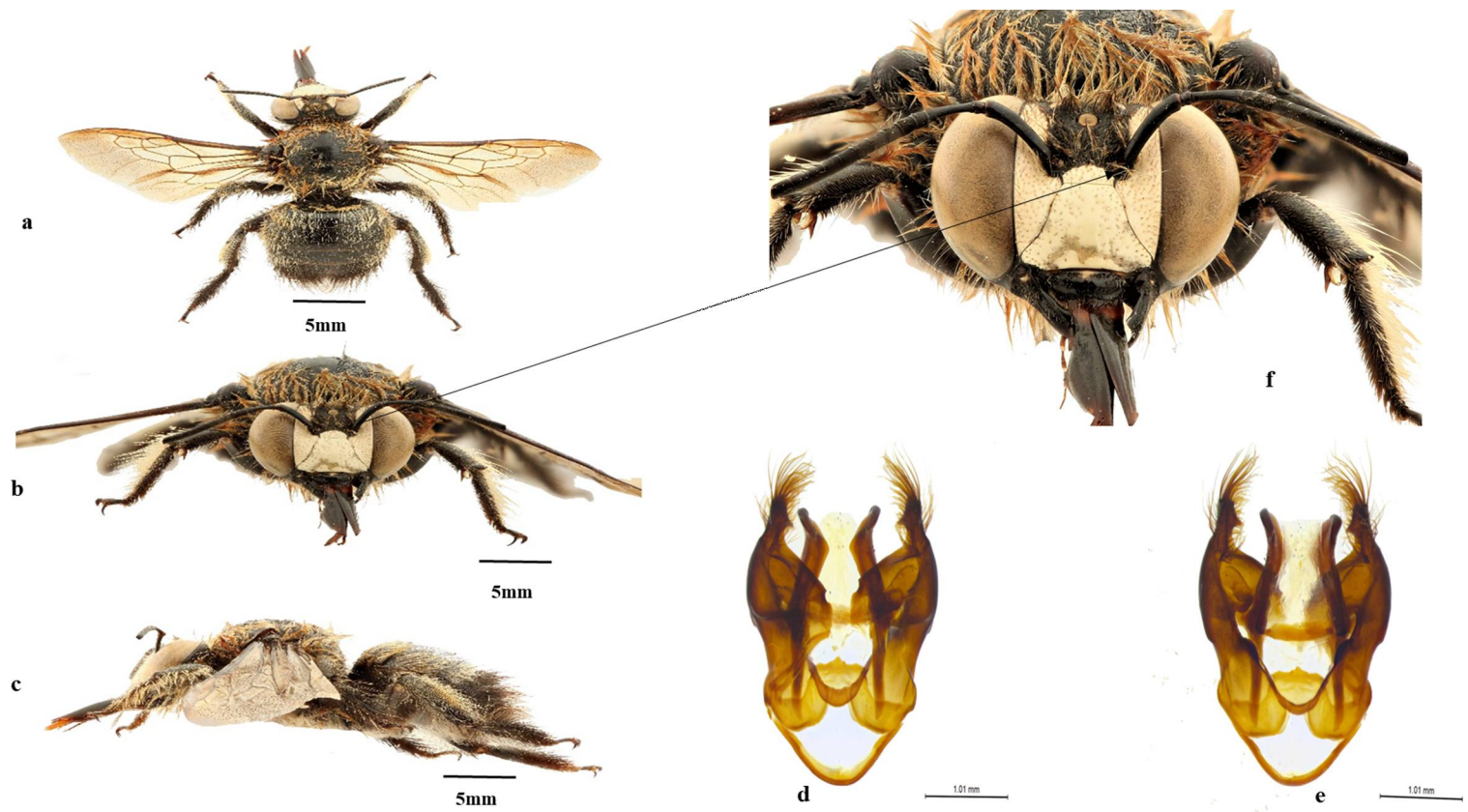


Plate 14: *Xylocopa (Zonohirsuta) dejeanii*, (♂)
a. Dorsal view **b.** frontal view **c.** lateral view **d-e.** genitalia; **d.** dorsal view **e.** ventral view **f.** face close up view

Table 14: Description of female characters of *Xylocopa (Zonohirsuta) dejeanii* (Lepeletier, 1841)

Body Description	Female (Plate 15)
Pubescence	Black; face with a mixture of pale and black hairs ; anterior portion of thorax dorsally and laterally with a collar of white pubescence; apex of abdomen with some ferruginous hairs.
Head	Inter-orbital distance slightly shorter than vertico-clypeal distance. Face flat, heavily punctate. Labrum weakly rugose. Genae occasionally with 1-2 shallow punctures. Punctures on dorsum of thorax a little sparser than those of males, those on disc of mesonotum and on anterior portion of scutellum of third-degree density. Knee-caps bifurcate, with distinct upper margin, lower projection usually narrower and longer than the upper.
Mesosoma	less densely punctate on the disc of mesonotum and on scutellum; front of mesonotum with erect dense white pubescence; wings dull fuscous with moderate purple effulgence
Metasoma	Inner teeth of posterior claws about 1/4 as long as the outer. Submedian processes of epipygium very weak, narrow. Median unpunctate band of abdominal sternites interrupted; hypopygium apically with a median keel.

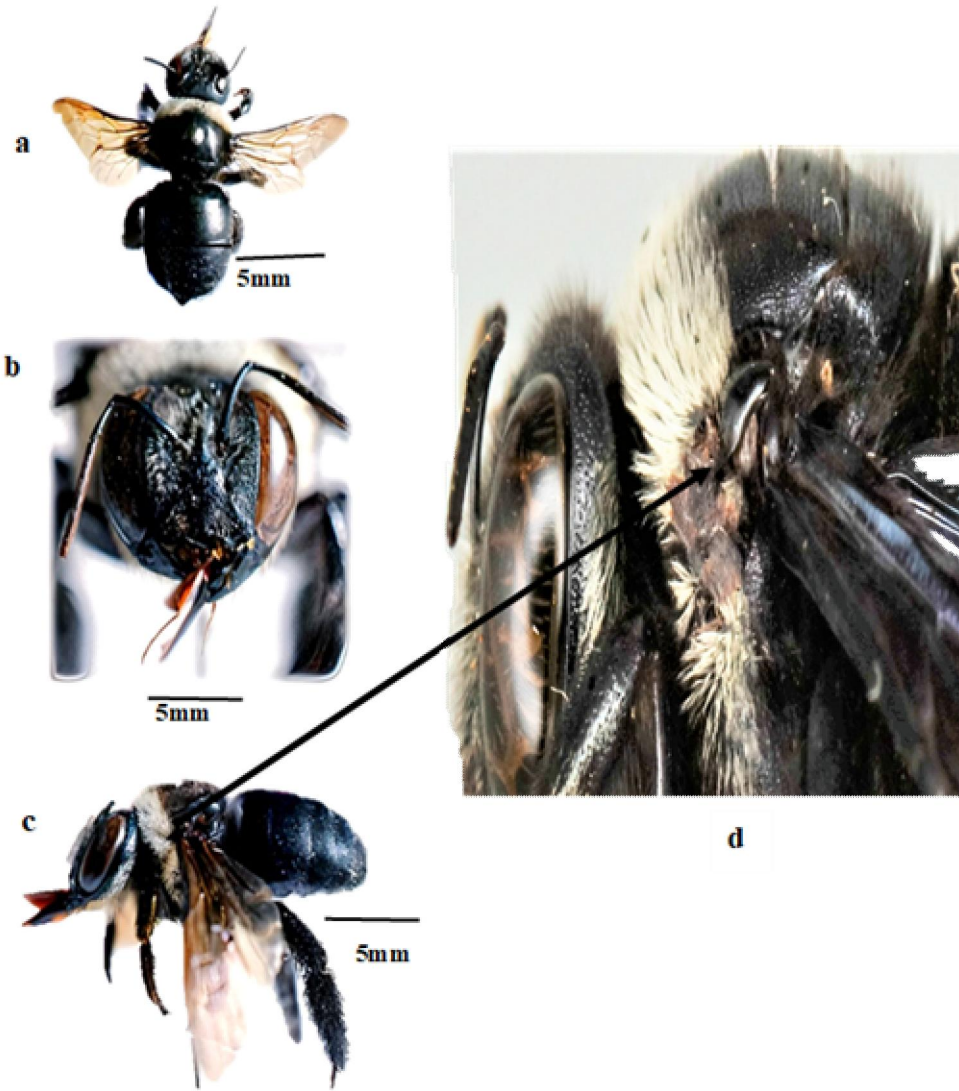


Plate 15: *Xylocopa (Zonohirsuta) dejeanii*, ♀
a. Dorsal view b. frontal view c. lateral view d. mesosoma

Table 15: Morphometry of *Xylocopa (Zonohirsuta) dejeanii* (Lepelletier, 1841) (N=10)

Parameters	Male	Female
	Mean \pm S.D (mm)	Mean \pm S.D (mm)
Total body length	17.00 \pm 2.08	20.15 \pm 1.83
Length of head	5.81 \pm 0.43	6.36 \pm 1.39
Width of head	7.48 \pm 0.51	7.84 \pm 1.26
Length of scape	2.45 \pm 0.24	2.65 \pm 0.52
Width of scape	0.36 \pm 0.07	0.33 \pm 0.01
Length of pedicel	0.26 \pm 0.03	0.22 \pm 0.03
Width of pedicel	0.29 \pm 0.03	0.28 \pm 0.02
Length of F1	1.11 \pm 0.13	1.16 \pm 0.27
Width of F1	0.25 \pm 0.03	0.23 \pm 0.05
Length of F2-F10 or F11	3.92 \pm 0.52	4.01 \pm 0.63
Inter antennal distance	1.03 \pm 0.23	1.16 \pm 0.13
Antenno-ocellar/ Alveolocellar distance	0.69 \pm 0.08	0.78 \pm 0.02
Length of mandible	2.30 \pm 0.24	2.40 \pm 0.45
Total tongue Length	9.56 \pm 2.13	7.77 \pm 0.58
Length of labial palpi	5.50 \pm 0.89	4.64 \pm 0.81
Length of clypeus	1.74 \pm 0.22	2.07 \pm 0.27
Width of clypeus	3.13 \pm 0.33	3.98 \pm 0.79
Clypeoantennal distance	0.59 \pm 0.04	0.63 \pm 0.10
Width of eye	1.76 \pm 0.01	1.71 \pm 0.24
Length of Mesosoma	10.50 \pm 0.97	8.28 \pm 1.08
Width of Mesosoma	9.63 \pm 1.17	8.89 \pm 1.71
Length of Forewing	25.13 \pm 1.69	24.93 \pm 5.90
Length of Hindwing	15.77 \pm 1.59	15.82 \pm 3.19
Length of 1st sub marginal cell	3.69 \pm 0.60	3.44 \pm 0.85
Length of 2nd sub marginal cell	2.43 \pm 0.39	2.38 \pm 0.59
Length of 3rd sub marginal cell	4.42 \pm 1.94	3.31 \pm 0.88
Length of fore tibia	3.87 \pm 0.47	3.86 \pm 0.77
Length of fore basitarsi	3.30 \pm 0.05	3.64 \pm 0.78
Length of hind tibia	7.69 \pm 0.62	5.14 \pm 0.79
Length of hind basitarsi	5.68 \pm 0.30	6.11 \pm 2.09
Length of metasoma	12.10 \pm 0.26	12.83 \pm 1.30
Width of metasoma	11.03 \pm 1.24	10.41 \pm 2.20
I metasomal segment length	1.73 \pm 0.26	2.12 \pm 0.28
II metasomal segment length	2.80 \pm 0.31	2.64 \pm 0.40

Remarks: Presently the subgenus *Zonohirsuta* is represented by five species in the world of which two species are from India (*X. bhowara* Ma and *X. dejeanii* Lepeletier). Hurd and Moure (1963) key to species of subgenus *Zonohirsuta* is not match with my specimens because in males eyes are more convergent above than below; ventral surface of hind femur deeply incised along the apical half and with a dentiform projection near middle as in *X. dejeanii* but pale hairs not extending beyond anterior margin of T2 in *X. (Zonohirsuta)* sp1. In females body integument black without metallic reflections in contrast blue or green metallic reflections in *X. xanti* Mocsáry. The present species was found nesting in fallen dead tree trunk in the forest.

4.7 Confirmation of *Xylocopa* spp. species using mt-CO1 sequence

In the present study mitochondrial gene fragment Cytochrome Oxidase subunit 1 (CO1) were amplified and sequenced to confirm the identity and to study the phylogenetic relationship of native *Xylocopa* population of J&K and Ladakh. A total of 14 geographical isolates covering four species (*X. valga*; *X. pubescens*; *X. fenestrata*; and *X. dejeanii*) were used to amplify around 630 base pairs fragment of CO1 gene. All the obtained sequences of *Xylocopa* species were submitted to NCBI Genbank nucleotide sequence databases (yet to receive the accession numbers). BLASTN search results of the obtained sequences confirmed the species identity of *X. valga*; *X. pubescens*; *X. fenestrata*; and *X. dejeanii* which is in agreement with morphological identity besides revealed the monophyletic nature of tribes of Xylocopinae (Fig. 2). The phylogenetic analyses and genetic variation among geographically collections (phylogeography) of the carpenter bees using the mitochondrial DNA genes (CO1) are given in Table 16.

Table 16: Confirmation of *Xylocopa* spp. species using mt-COI sequence

Sample ID	<i>mt-COI</i> seq.	Acc. No.	% Identity	Confirmed species
JK-1	TATATTATATATTATATTAGCTTTATGATCAGG AATAATTGGAACATCAATAAGATTTATTATTC GTATAGAATTAAGAATTCCTGGAAATTGAATT AATAATGATCAAATTTATAATTCATTAGTAAC AGCTCATGCATTTTTAATAATTTTTTTTATAGT TATACCTTTTATAAATGGTGGATTGGAAATTG ATTAATCCATTAATACTAGGTTACCAGATAT AGCATTCCCTCGAATAAATAATATTAGATTTTG ATTATTACCTCCATCATTAAATATATTATTATC TAGAAATATATTTTATCCAAGACCAGGAACCTG GATGAACATTTATCCTCCACTTCTTCATTTTT ATATCATCCATCGCCTTCAGTTGATTTAATAAT TTTTCTTTACATTTATCTGGAATTTTCATCAATT ATAGGAGCAATAAATTTTATAGTTACAATCAT AATAATAAAAAATATTCTATAAATTATGATA AAATTAATTTATTTTCATGATCAGTTTTTATTA CTGCAATTTATTACTTTTATCTCTACCAGTTTT AG	ON377280.1 KX673520.1 KX673519.1 KX673518.1 KX673517.1 KT960852.1	94.6	<i>Xylocopa pubescens</i>
JK-2	ATAAAGATATTGGTATATTATATATATTTTAG CTTTATGAGCAGGTATATTAGGAACATCAATA AGAATAATTATTCGTATAGAATTAAGAATTC TGGATCCGAAATTAATAATGATCAAATTTATA ATTCAATAATTACAGCTCATGCATTTTTAATAA TTTTTTTTATAGTAATACCTTTTATAATGGTG GATTTGGAAATTGATTAATTTCAATAATATTA GGCTTACCTGATATAGCTTTTCCACGAATAAAT AATATTAGATTTTGATTATTACCACCTTCACTT ATTTTATTAATTTTAAGAAATTTATTTAATCCA AGACCTGGAACCTGGTTGA ACTATTTATCCTCCT TTATCATCATTTTTATATCATTATCTCCTGCTG TAGATTTAATAATTTTTCTTTACATATTTCTG GAATTTTCATCAATTATAGGAGCTATAAATTTA TTGTGACAATTATAAATAAAAAATATTCA ATAAATTATGATAAAAAATTTTATTGTCATGA TCAGTATTATTACAGCTATTTATTATTATTA TCATTACCTGTTTTAGCTGGAGCAATTACTATA TTATTTTATGATCGAAATTTAATACATCATTT TTGATCCAATAG	ON331707.1 OM149840.1 MK904782.1 MK904781.1 MN163114.1 KX673524.1	93.6	<i>Xylocopa fenestrata</i>
JK-3	TCGAATAAATAATATTAGTTTTTGATTATTACC TCCATCATTAAATTTTATTATTAATAAGAAATTT ATTTTATTTAAGACCTGGAACCTGGATGAACAA TTTATCCTCCTTTATCATCATTTTTTATATCATCC TTCTCCTTCAGTTGATTTAATAATTTTTTCATTA CATATTCTGGATTATCTCAATTATAGGAGCT ATAAATTTTATAGTTACAATTATAAATAATGAA AAATGTATCAATAAATTTATGATAAATTAATTT TATTTCTTGATCAGTATTATTACAGCTATTTT ATTATTATTATCATTACCTGTATTAGCTGGAGC TATTACTATATTATTATTGATCGAAATTTTAA TACATCTTTTTTTGATCCAATAGGTGGGGGAG ATCCAATTTTATTTCAACATTTATTT	MH319133.1 KJ838707.1 KJ836736.1	91.7	<i>Xylocopa valga</i>

<p>JK-4</p>	<p>TTTATAATTGGTGGATTGGAAAATTGATTAATT CCTTAAATATTAGGATTACCAGATATAGCATT CCTCGAATAAATAATATTAGATTTTGATTATTA CCACCTTCTTTAATTATATTATTAGTTAGGAAT TTATTTTATCCTAGACCAGGAACAGGATGAAC AATTTATCCTCCTTTATCATTATTTTTATATCAT CCATCTCCTTCAGTTGATTAAATAATTTTTCTT TACATATTCAGGTATTTTCATCAATTATAGGTG CAATAAAATTTTATGGTTACTATTATAATAATAA AAAATATTTCAATAAAATTATGATAAAATTAAT TTATTTTCTTGATCTGTTTTTATTACAGCAATTT TATTATTATTATCATTACCTGTATTAGCTGGTG CAATTACTATATTATTATTGATCGAAATTTTA ATACTTCTTTTTTGGATCCAATAGGAGGTGGTG ATCCAATTTTATTATGTAAATTAATTTAAGTA ATAATAATGTATTTGATCATTAGGTTTTGTAA TTTTATTTACTATTGGAGGATTAAGTGGTATTA TATTATCAAATTCATCTGTTGATATTATTTTAC ATGATACTTATTATGTAGTTGGTCATTTTCATT ATGTATTATCAATAGGAGCAGTATTTGCTATTA TTCAAGATTTATTCATTGATATCCTTTAATTT ATGGATTTATATTAATCAAAGTGATTAAG GTTCAATTTATTTTTATATTT</p>	<p>EU446004.1 AF153114.1 EU446004</p>	<p>95.6</p>	<p><i>Xylocopa dejeanii</i></p>
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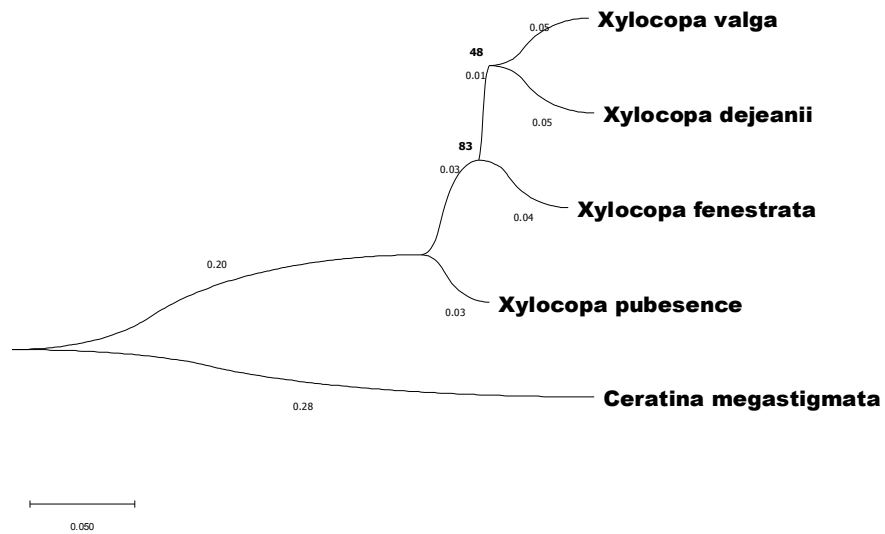


Fig. 2: Phylogenetic tree with bootstrap support showing clustering of different species of *Xylocopa* for partial CO1 sequences

Objective 2: To determine the floral resources of *Xylocopa* spp. in different agro-ecosystems of Northwest Himalayan range of J&K and Ladakh.

4.8 Foraging plants of *Xylocopa* spp.

Xylocopa spp. are polylectic in nature, meaning that it shows no specialisation as far as food acquisition is concerned and it visits flowers of numerous plants not related with each other so as to feed on pollen and nectar. The activity of carpenter bees was observed on different flowering plants during collection of these bees. Fifty-three species of flowering plants belonging to 10 families were recorded as associated with these carpenter bees including Asteraceae (11 spp.), Cucurbitaceae (3 spp.), Fabaceae (4 spp.), Lamiaceae (11 spp.), Rosaceae (10 spp.), solanaceae (4 spp.), Oleraraceaea (1 sp.), Bignoniaceae (2 spp.), Rutaceae (3 spp.), Malvaceae (4 spp.) as shown in Table 17.

Table 17: List of floral resources associated with Large carpenter bees of J&K & Ladakh

Family	Plant species	Common name	Floral Reward N=Nectar P=Pollen	<i>Xylocopa</i> spp. visited
Malvaceae	<i>Alcea rosea</i>	Common hollyhock	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x.dejeanii</i> , <i>X. pubescens</i>
	<i>Abelmoschus esculentus</i>	Lady's-finger	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x.dejeanii</i> , <i>X. pubescens</i>
	Hibiscus rosa-sinensis	China rose	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x.dejeanii</i> , <i>X. pubescens</i>
	<i>Lavatera cashmiriana</i>	Kashmir Mallow	NP	<i>X.valga</i>
Cucurbitaceae	<i>Cucumis sativus</i>	cucumber	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x.dejeanii</i> , <i>X. pubescens</i>
	<i>Cucurbita maxima</i>	Common squash	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x.dejeanii</i> , <i>X. pubescens</i>
	<i>Citrullus lanatus</i>	watermelon	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x.dejeanii</i> , <i>X. pubescens</i>
Rutaceae	<i>citrus limmetoides</i>	Palestinian sweet lime	NP	<i>X.fenestrata</i> , <i>X. pubescens</i>
	<i>Citrus limon</i>	lemon	NP	<i>X.fenestrata</i> , <i>X. pubescens</i>
	<i>Citrus reticulata</i>	Mandarin orange	NP	<i>X.fenestrata</i> , <i>X. pubescens</i>
Fabaceae	<i>Phaseolus vulgaris</i>	Common bean	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x.dejeanii</i> , <i>X. pubescens</i>
	<i>Pisum sativum</i>	pea	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x.dejeanii</i> , <i>X. pubescens</i>
	<i>Trifolium pratense</i>	Red Clover	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x.dejeanii</i> , <i>X. pubescens</i>
	<i>Trifolium repens</i>	White Clover	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x.dejeanii</i> , <i>X. pubescens</i>
	<i>Cercis siliquastrum</i>	Judas tree	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x.dejeanii</i> , <i>X. pubescens</i>
Bignoniaceae	<i>Catalpa bignonioides</i>	Indian bean tree	NP	<i>X. valga</i>
Oleraceae	<i>Forsythia viridissima</i>	Chinese golden bell tree	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x.dejeanii</i> , <i>X. pubescens</i>

Asteraceae	<i>Ageratum houstonianum</i>	Bluemink	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x. dejeanii</i> , <i>X. pubescens</i>
	<i>Arctium lappa</i>	Greater burdock	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x. dejeanii</i> , <i>X. pubescens</i>
	<i>Calendula officinalis</i>	Pot marigold	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x. dejeanii</i> , <i>X. pubescens</i>
	<i>Carduus edelbergii</i>	Cotton thistle	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x. dejeanii</i> , <i>X. pubescens</i>
	<i>Chrysanthemum coronarium</i>	Crown daisy	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x. dejeanii</i> , <i>X. pubescens</i>
	<i>Cirsium arvense</i>	Creeping thistle	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x. dejeanii</i> , <i>X. pubescens</i>
	<i>Cirsium falconeri</i>	Falconer's thistle	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x. dejeanii</i> , <i>X. pubescens</i>
	<i>Cirsium vulgare</i>	Spear thistle	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x. dejeanii</i> , <i>X. pubescens</i>
	<i>Taraxacum officinale</i>	common dandelion	NP	<i>X.valga</i> , <i>x. dejeanii</i>
	<i>Helianthus annuus</i>	sunflower	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x. dejeanii</i> , <i>X. pubescens</i>
	<i>Zinnia elegans</i>	common zinnia	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x. dejeanii</i> , <i>X. pubescens</i>
Solanaceae	<i>Hyoscyamus niger</i>	stinking nightshade	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x. dejeanii</i> , <i>X. pubescens</i>
	<i>Lycopersicon esculentum</i>	Tomato	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x. dejeanii</i> , <i>X. pubescens</i>
	<i>Solanum nigrum</i>	Black nightshade	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x. dejeanii</i> , <i>X. pubescens</i>
	<i>Solanum tuberosum</i>	Potato	NP	<i>X.valga</i>
Lamiaceae	<i>Hyssopus officinalis</i>	Hyssop	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x. dejeanii</i> , <i>X. pubescens</i>
	<i>Marrubium vulgare</i>	White horehound	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x. dejeanii</i> , <i>X. pubescens</i>
	<i>Mentha longifolia</i>	Mint	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x. dejeanii</i> , <i>X. pubescens</i>
	<i>Mentha arvensis</i>	Field mint/wild	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x. dejeanii</i> , <i>X. pubescens</i>

	<i>Nepeta cataria</i>	Cat mint	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x. dejeanii</i> , <i>X. pubescens</i>
	<i>Nepeta discolor</i>	catnip	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x. dejeanii</i> , <i>X. pubescens</i>
	<i>Prunella vulgaris</i>	Carpenter's herb	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x. dejeanii</i> , <i>X. pubescens</i>
	<i>Salvia hians</i>	Himalayan Blue Sage	NP	<i>X.valga</i> , <i>x. dejeanii</i> ,
	<i>Stachys sericea</i>	Melissa-Leaf Woundwort	NP	<i>X.valga</i>
	<i>Thymus serpyllum</i>	creeping thyme	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x. dejeanii</i> , <i>X. pubescens</i>
	<i>Thymus linearis</i>	Himalayan Thyme	NP	<i>X.valga</i>
Rosaceae	<i>Agrimonia pilosa</i>	hairy agrimony	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x. dejeanii</i> , <i>X. pubescens</i>
	<i>Cydonia oblonga</i>	Quince	NP	<i>X.valga</i> , <i>x. dejeanii</i> ,
	<i>Eriobotryia japonica</i>	Loquat	NP	<i>X.valga</i> , <i>x. dejeanii</i> ,
	<i>Fragaria ananassa</i>	strawberry	NP	<i>X.valga</i> , <i>x. dejeanii</i> ,
	<i>Malus domestica</i>	apple	NP	<i>X.valga</i> , <i>x. dejeanii</i> , <i>X.valga</i> , <i>x. dejeanii</i> ,
	<i>Prunus armeniaca</i>	Apricot	NP	<i>X.valga</i> , <i>x. dejeanii</i> ,
	<i>Prunus domestica</i>	plum	NP	<i>X.valga</i> , <i>x. dejeanii</i> ,
	<i>Prunus persica</i>	peach	NP	<i>X.valga</i> , <i>x. dejeanii</i> ,
	<i>Pyrus communis</i>	pear	NP	<i>X.valga</i> , <i>x. dejeanii</i> ,
	<i>Rosa brunonii</i>	Himalayan musk rose	NP	<i>X.valga</i> , <i>X.fenestrata</i> , <i>x. dejeanii</i> , <i>X. pubescens</i>

Objective 3: To study the nesting behaviour of dominant species of *Xylocopa* in Kashmir valley

Different nesting structures *viz.*, wooden blocks, wooden logs and Bamboo canes were installed at different locations in district Ganderbal (Table 18). *X. valga* was the only species found during the expedition in Kashmir valley. The *X. valga* was found multiplying at the rate of one generation a year in the Kashmir valley and lead a solitary life.

4.9 Nest Architecture and Structure of *X. valga* in Kashmir

X. valga nests were found branched with more than one gallery. The branched nests were found in Poplar (*Populus deltoides*), Apple tree wood (*Malus domestica*) and Pear tree wood (*Pyrus communis*). The *X. valga* did not use the bamboo reeds as nesting sites and abandoned them. Nests were mostly found close to each other. The opening directions/entrance of the nests were mostly towards west and south. The nest was built on dead wood of Poplar, Apple and Pear of about 258.85 ± 10.41 cm above the soil surface.

The detail of nests constructed by *Xylocopa valga* is presented in Table 19 & 20 (Plate 16). The cells constructed were shaped like a long oval cylinder, where average nest length was 29.50 ± 1.84 cm. The number of cells per nest ranged from 5–9 with a mean of 7.17 ± 2.14 per nest. The average number of galleries recorded were 2.32 ± 1.14 . An average of seven females and one male emerged from each nest. These nesting architectural details will help to develop novel artificial trap nesting in the field and in conservation of carpenter bees.

The study reported the occurrence of kleptoparasitism by *Allorhynchium metallicum* (de Saussure, 1852) in the nests of *Xylocopa valga* for the first time. The *Allorhynchium metallicum* (de Saussure, 1852) is also first time identified and reported from the Kashmir valley. It belongs to family Eumenidae of vespoidea subfamily of order hymenoptera. The genus was first described by van der Vecht in 1963 and are commonly called as potter wasps. They are solitary and predatory in nature.

They nested in our artificial nesting structures but were more prominent in bamboo reeds and occupied almost fifty per cent of the structures installed (Plate 17). The complete biology is not yet studied and needs further research to mention the amount of competition it can had with the *Xylocopa* spp. and other native bees that reside in wooden logs.

Table 18: Details of the locations for studying nesting behaviour of *Xylocopa valga*

S.No.	District	Location	Latitude	longitude	Altitude (m AMSL)
1	GANDERBAL	Wakura	34° 13' 19"N	74° 41'41"E	1630
2		kurhama	34° 14' 12"N	74° 42'21"E	1610
3		lar	34° 16'43"N	74° 46'37"E	1717
4		Gutlibagh	34° 16'33"N	74° 49'39"E	1778
5		khanpora	34° 12' 13"N	74° 40'51"E	1600

Table 19: Nesting characteristics of *Xylocopa (Xylocopa) valga* in wooden logs (N=9)

Nest Characters	Measurements (cm)		
	Mean±S.D.	Min.	Max.
Nest length (cm)	29.50±1.84	27.50	32.00
Nest entrance hole (cm)	1.53±0.26	1.20	2.00
No. of galleries/nest	2.32± 1.14	2.02	3.24
Number of cells/nest	7.17±2.14	5.00	9.00
Inner most cell length (1st cell)	2.17±0.21	1.67	2.50
individual cell length	2.01±0.08	1.90	2.10
Cell diameter	6.35±1.20	5.05	7.12
Thickness of diaphragm (cm)	0.92±0.10	0.80	1.00

Table 20: Nest contents of *Xylocopa valga*.

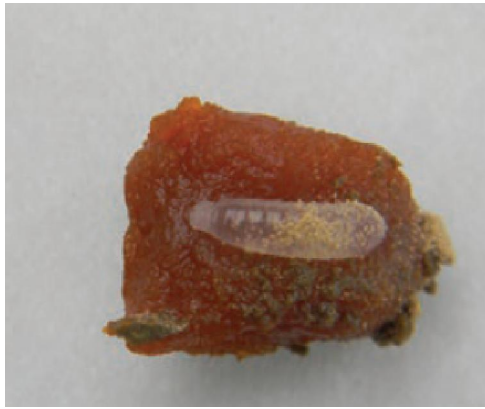
Nest No. & Date of Dissection	Length of nest (mm)	Distance from surface (cm)	No. of galleries	No. of cells/gallery	Cell length (mm)	Content of gallery			
						Egg	Larva	Pupa	Adult
1, Aug, 18, 2020	304.8	250.7	3	3	20	0	0	4	2 (2♀)
2, Aug, 28, 2020	310.7	290.4	2	5	23	0	3	0	0
3, Sep, 17, 2020	340.5	200.3	3	4	22	0	0	5	3 (3♀)
4, Sep, 25, 2020	300.6	270.9	3	3	21	0	0	0	7 (7♀)
5, July, 28, 2021	321.8	230.7	4	3	20	0	0	2	5 (4♀, 1♂)
6, July, 29, 2021	316.7	260.2	3	4	19	0	0	4	4 (4♀)
7, Aug, 12, 2021	330.2	280.4	2	3	23	0	2	0	0
8, Sep, 10, 2021	350.5	300.5	1	4	21	0	0	0	4 (4♀)
9, Aug, 05, 2022	307.4	245.6	3	3	20	0	0	3	2 (2♀)
Mean±SD	320.35± 5.67	258.85± 10.41	2.4±0.77	3.2± 0.33	18.9±1.12	0.0±0.0	0.55±0.37	2±0.68	3±1.12



a



b



c



d



e



f

Plate 16: The structure and composition of nest of *X. valga*

(a) nest entrance **(b)** nest dissected **(c)** egg on pollen mass **(d)** larva in the cell **(e)** Pupa **(f)** adult emerging from the log.



Plate 17: Occurrence of kleptoparasitism by *Allorhynchium metallicum* on the nests of *X. valga* (a) wooden log entrance sealed (b) bamboo sticks entrance sealed (c) individual bamboo log (d) larvae of *Allorhynchium metallicum* in bamboo log (e) single larva on hand (f) Adult *Allorhynchium metallicum*

Chapter-5

DISCUSSION

The studies on “**Diversity of *Xylocopa* spp. in different agro-ecosystems of Northwestern Himalayas**” were taken up with the objective to document the diversity of different *Xylocopa* spp. to explore their floral resources in different climatic zones of Jammu & Kashmir and Ladakh. and examine their nesting behaviour. The findings of the present study are briefly discussed as under:

5.1 Diversity of *Xylocopa* spp. in Jammu and Kashmir and Ladakh

A total of 302 specimens of carpenter bees, representing 04 species were collected. The bees were identified to their respective subfamilies, generic, sub-generic and species levels. A few earlier studies have attempted to prepare faunal lists of bees of particular regions of Kashmir & Jammu (Raj and Mattu, 2014; Ara *et al.*, 2019; Abrol *et al.*, 2012; Tara *et al.*, 2014). In continuation of these efforts, this study attempted to know the species diversity across the agro-climatic zones of Jammu & Kashmir and Ladakh.

During the present study, the Genus *Xylocopa* included four subgenera and four species. The subgenus *Ctenoxylocopa* Michener was found represented by *X. fenestrata* (Fabricius), subgenus *Koptortosoma* Gribodo by *X. pubescens* (Spinola), subgenus *Xylocopa* by *X. valga* (Latreille), and subgenus *Zonohirsuta* Ma by *X. dejeanii* (Lepeletier). The occurrence of *X. fenestrata* and *X. pubescens* in the region of Jammu was earlier reported by Abrol *et al.* (2012) and Raj and Mattu (2014) and still constitutes an important part of mellitofauna of the region. These two species have been excellent pollinators of the wide variety of agricultural and horticultural crops in the area.

The *X. dejeanii* collected from Budhal and Patnitop area of Jammu region is a kind of temperate species owing to its climate of the area. Earlier it was mis-

identified as *X. collaris* (Tara *et al.*, 2014), however, that is an African species described by Olivier (1789) and thus can't be applied to the Asian species.

The valley of Kashmir is represented by only one species of *Xylocopa i.e.*, *X. valga*. The previous researchers have reported more than one species including *X. violacea* and *X. iris* (Ara *et al.*, 2019; Gupta and Yanega, 2003). However, not a single specimen of these species could be collected or captured during the field surveys in Kashmir or other regions of Jammu. However, multiple specimens of *X. valga* from Kashmir and Ladakh areas were examined that have been identified under these names. Thus, such records of *X. violacea* and *X. iris* for Kashmir valley seem to have been misidentified specimens. Yet, still the possibility of existence of these species in Kashmir or other nearby regions cannot be ruled out entirely because of the proximity of this province to Pakistan, china, and Afghanistan. Further, as per the literature available, these species, were collected during early 1900's and have not been collected since then. The confusion is obvious as it is very difficult to have a clear view of the species without having the specimens of both sexes. Therefore, further work on these aspects are warranted in future.

The discovery of the presence of *X. valga* for the first time in the high altitudes of Ladakh shows that the range of this species has been expanding, owing to the changing thermal conditions within the region. Although references are scarce in literature from neighbouring countries, however, there are at least some indications that the species has been expanding only recently, notably in China where it was reported from Inner Mongolia to Tibet and north western regions with higher altitudes (He and Zhu, 2020). It is very likely that the environment and habitat is getting more suitable for *X. valga*. On the one hand there is an abundance of several agri and horticultural vegetation as well as ornamental plants cultivated in neighbouring villages and town settlements that are used for feeding and to collect pollen.

Compared to the few attempts made in the past to document *Xylocopa* species of Jammu & Kashmir and Ladakh, the present study is perhaps the only one that has attempted to quantify the same. The present study with a record of 04 species is probably the most exhaustive. Difference between the agro-climatic zones with respect to carpenter bee diversity has been significant. The high diversity of bees could be attributed to the high floral diversity. In several other studies, plant diversity has been established as an important correlate of bee diversity (Holzschuh *et al.*, 2007). The availability of nesting sites has also been reported as contributing to high diversity of bees (Araujo *et al.*, 2006; Kearns *et al.*, 2009).

The phylogenetic analysis of 14 geographical isolates covering four species (*X. valga*; *X. pubescens*; *X. fenestrata*; and *X. dejeanii*) of *Xylocopa* were done using 630 base pairs fragment of CO1 gene. The analysis revealed the monophyletic nature of tribes of Xylocopinae.

5.2 Foraging plants of *Xylocopa* spp.

The relationship between bees and flowers is mutualistic, the former for food and the latter for pollination which is a key aspect in the sexual reproduction of plants, enabled by appropriate structural and functional characteristics (Raju and Rao, 2006). Carpenter bees are economically important as globally reported to pollinate diverse crops, including passion fruit, squash, tomato, Brazilian nut tree, and eggplant (Kesar 2010; Giannini *et al.*, 2015).

During present study, the activity of *Xylocopa* was observed on different flowering plants while collecting these bees. Fifty-three species of flowering plants belonging to 10 families were recorded as associated with these bees including Asteraceae (11 spp.), Cucurbitaceae (3 spp.), Fabaceae (4 spp.), Lamiaceae (11 spp.), Rosaceae (10 spp.), solanaceae (4 spp.), Oleraraceaea (1 sp), Bignoniaceae (2 spp.), Rutaceae (3 spp.), Malvaceae (4 spp.).

Xylocopa are versatile in terms of foraging as they can tolerate high ambient temperatures during foraging, and most species are inactive at low temperatures except *X. valga*. For example, the lower activity temperature thresholds are 23° C for *X. capitate* (Luow & Nicolson, 1983), 21° C for *X. sulcatipes*, and 18° C for *X. pubescens* (Gerling *et al.*, 1983). Flower visit rates in *X. olivieri* are highest at a combination of high (25–35°C) temperatures and low (1–100 Lux) illumination levels (Gottlieb *et al.*, 2005). Schaffer *et al.*, 1979 observed *X. arizonensis* individuals that foraged on *Agave schottii* together with honey bees and bumble bees active mainly during the late morning hours, while honey bees and bumble bees more crepuscular. They suggested these patterns to reflect low competitive ability, together with high thermal tolerance, in the carpenter bees. Further, *X. varipuncta* was found to maintain flight activity within an ambient temperature range of 12-40°C by Heinrich and Buchmann (1986). This heat tolerance suggests good heat regulation ability in carpenter bees, possibly controlled by a thermoregulatory centre in the prothorax (Volynchik *et al.*, 2006).

The activity period of some species, for example, *X. sulcatipes*, *X. cearensis*, and *X. ordinaria*, spans most of the daylight hours (Viana *et al.*, 2002). In other species (such as *X. pubescens*, *X. tabaniformis*, and *X. olivieri*), activity is crepuscular (Bernardino and Gaglianone., 2008) A few species are nocturnal: *X. tenuiscapa* forages on its pollen host on moonless nights (Somanathan and Borges, 2001), and *X. tranquebarica* (Burgett *et al.*, 2005) has been observed foraging on moonlit nights.

5.3 Nesting behaviour of dominant species of *Xylocopa* in Kashmir valley

The *Xylocopa* spp. typically nests in woody material mainly consisting of the branching type and the non-branching type, also called the straight-chain type (Gerling *et al.*, 1989, Steen and Schwarz 2000, Bernardino and Gaglianone 2008, Prager 2008, Prager and Hunter 2011, Rahman and Deka 2011, Hannan *et al.*, 2012). Different species of Xylocopinae build different nest structures. Relationships exist between the nest architecture and the distribution of cells

within the nest, the cell size, the efficiency of bee bread storage and the sensitivity to parasitism (Steen and Schwarz 2000, Prager and Hunter 2011). However, *Proxyllocopa* is the only subgenus in *Xylocopa* that nests in the soil. It is reported to contain sixteen species, widely distributed in Albania, Greece, Israel, and the desert areas of Western China. *X. olivieri* and *X. rufa* are the examples that nest on slopes with a thick soil layer.

The wood boring species like *X. pubescens* and *X. fenestrata* shows almost similar nest structure. *X. pubescens* has little larger and wider nest entrance compared to *X. fenestrata*, probably due to the differences in the size of the bees. The subtropical carpenter bee, *X. fenestrata*, prefers to nest in the dead wood of *Arundo* sp. and bamboo to build a long tunnel of 23-30 mm with internal diameter of 10–12 mm (Sihag 1993a; Rahman and Deka, 2011).

The nesting biology and architect of *X. valga*, which is the most commonly and widely distributed species of the large carpenter from Kashmir valley was studied for the first time. During the study, it was found solitary and univoltine. It nested in the wooden structures and overwintered as an adult. The females started feeding in early May of the following year and built their breeding sites near their wintering nests. The cell constructed by *X. valga* shaped like a long oval cylinder, where average nest length was 29.50 ± 1.84 cm. The number of cells per nest ranged from 5-9 with a mean of 7.17 ± 2.14 per nest. The average number of galleries recorded were 2.32 ± 1.14 . An average of seven females and one male emerged from the nest, which was also reported by Sihag (1993b) in *X. fenestrata*, hence known as female-biased brood.

During the present study, *X. valga* was first time reared in artificial nesting structures composed of wooden logs, blocks of Apple, pear and poplar and bamboo reeds. The effort was made so that the presence of *X. valga* in wooden logs would help in devising more efficient and novel artificial nesting structures. The bamboo reeds, however, were not preferred by this species as it makes

multiple galleries that is not possible in bamboo structures besides having more prone to external calamities and predators.

The majority of the researchers concluded that the species has one generation annually. During the present study, the overwintered adults emerged in early spring (from mid-April). Following mating, fertilised females started creating nests, usually in wood of dead tree. The female made a tunnel with a series of 10-12 brood cells, which were separated by partitions built using scraped wood shavings. Each cell was filled with pollen, and only single egg laid on pollen. After laying eggs, the female stayed inside and safeguarded the nest. Emergence of young adults took place from the end of July to the beginning of September. They did not leave wood and overwintered in the cells. The mother usually died after offspring emergence; however, sometimes she overwintered and built a nest again in next spring. Some sources say that the overwintering stage is a pre-pupa in cocoon. Malyshev (1931) observed that young *X. valga* specimens leave the nest in the fall and overwinter in the soil.

Although there is a remarkable diversity of species of *Xylocopa* in Asia (Raju and Rao 2006), there have been comparatively few studies on their nesting biology and floral associations outside of Middle East, most having been undertaken on a subset of relatively common taxa (Iwata 1938; Maeta *et al.*, 1985; Silveira 2002; Sadeh *et al.*, 2007; Engel *et al.*, 2012).

The occurrence of kleptoparasitism by *Allorhynchium metallicum* (de Saussure, 1852) in the nests of *Xylocopa valga* is not new to the order Hymenoptera. The cuckoo bees are the best examples for kleptoparasitism as mated female cuckoo bees hover low over the ground and use olfactory cues to locate suitable host burrows (Cane 1983). Once she has found a burrow, she waits for the adult bee to leave before invading the nest to oviposit her own eggs. One-to-two eggs are typically deposited into the wall of a single egg cell. Cuckoo bee first-instar larvae are prognathous (have forward-facing jaws) and have long, sickle-shaped mandibles. Once the cuckoo bee egg hatches, the larva uses its

specialized mandibles to kill other eggs or larvae, including conspecifics and then feed upon the pollen ball (Michener 2000). The larva then pupates within the host cell and later emerge as an adult. The same phenomenon was found during the present study where *Allorhynchium metallicum* utilized the wooden nests that were occupied by *Xylocopa valga*. However, there is no evidences that they are threat to the *Xylocopa valga* and other pollinators till now and further study is warranted.

Chapter-6

SUMMARY & CONCLUSION

The present study entitled “**Diversity of *Xylocopa* spp. (Hymenoptera: Apidae) in Northwest Himalayan Range of J&K and Ladakh**” covered the taxonomic review, molecular phylogeny and biological attributes of the large carpenter bees (*Xylocopa* spp.). A total of 302 specimens of large carpenter bees collected from various parts of Jammu & Kashmir and Ladakh were examined. The salient findings of the investigation are summarized below:

- The study revealed the presence of four species viz., *X. valga*, *X. fenestrata*, *X. pubescens*, *X. dejeanii* belonging to four sub-genera in the subfamily Xylocopinae from Jammu & Kashmir and Ladakh. All the taxa of the subfamily dealt herewith were described. Illustrations of habitus and male genitalia were presented on the basis of the keys devised for the identification of tribe, genera and species in the subfamily Xylocopinae occurring in Jammu & Kashmir and Ladakh. A checklist along with distribution for all the species of Xylocopinae from India was prepared and presented.
- The study did not add a new species but cleared various confusions and misnomers pertaining to already present species in the area thus helped taxonomists to have a clear and holistic view about the large carpenter bee fauna of Jammu & Kashmir and Ladakh.
- The Genus *Xylocopa* was represented by four subgenera and four species, viz., subgenus *Ctenoxylocopa* Michener represented by *X. fenestrata* (Fabricius), subgenus *Koptortosoma* Gribodo by *X. pubescens* (Spinola), subgenus *Xylocopa* by *X. valga* (Latreille), and subgenus *Zonohirsuta* Ma by *X. dejeanii* (Lepeletier).

- The phylogenetic analysis of 14 geographical isolates covering four species (*X. valga*; *X. pubescence*; *X. fenestrata*; and *X. dejeanii*) of *Xylocopa* carried out using 630 base pairs fragment of CO1 gene revealed the monophyletic nature of tribes of Xylocopinae.
- Fifty-three species of flowering plants belonging to 10 families were recorded as associated with *Xylocopa* including Asteraceae (11 spp.), Cucurbitaceae (3 spp.), Fabaceae (4 spp.), Lamiaceae (11 spp.), Rosaceae (10 spp.), solanaceae (4 spp.), Oleraraceaea (1 sp), Bignoniaceae (2 spp.), Rutaceae (3 spp.), Malvaceae (4 spp.).
- The nesting sites of *Xylocopa valga* were recorded at five different locations of District Ganderbal. The artificial nesting sites included use of wooden logs /wooden blocks /bamboo sticks of multiple dimensions to study the nesting biology and behaviour of large carpenter bee.
- The study revealed maximum invasion of *X. valga* in wooden logs of apple, pear and poplar, however, no nest was observed in bamboo sticks.
- The nesting architecture was recorded for *X. valga* where average nest length was 29.50 ± 1.84 cm. The number of cells per nest ranged from 5–9 with a mean of 7.17 ± 2.14 per nest. The average number of galleries recorded were 2.32 ± 1.14 . An average of seven females and one males were emerged from the nest.

The study concluded that the large carpenter bees (*Xylocopa* spp.) are important part of our mellitofauna. They serve as important pollinators of both horticultural and agricultural crops in J&K and Ladakh region. The ambiguity over the presence of multiple species of *Xylocopa* in Kashmir has been cleared in the light of taxonomy and molecular data. Presently, only four species viz., *X. valga*, *X. fenestrata*, *X. pubescens*, *X. dejeanii* belonging to four sub-genera in the subfamily Xylocopinae exist in Jammu & Kashmir and Ladakh. These bees show polylectic behaviour and are adapted to wide climatic conditions from temperate,

tropical, subtropical and cold arid conditions showing its flexibility in using the specie for pollination services around the world. The *Xylocopa* spp. explored from Kashmir region being a solitary and univoltine nested in dead wooden logs/blocks can be reared in artificial structures. The study insights the use of these artificial structures at proper time and season can help in green house pollination of some of the important crops like tomato, melons, cucumbers etc. owing to its nature of buzz pollination.

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CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner. Dr. Uma Shankar, Professor, Division of Entomology, FoA, SKUAST-Jammu during Viva-Voce examination held on 06-12-2022 have been incorporated in the manuscript entitled **“Diversity of *Xylocopa* spp. (Hymenoptera: Apidae) in Northwest Himalayan Range of J&K and Ladakh”** submitted by **Mr. Umer Bin Farook (Regd. No. 2019-868-D)**.

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