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Diversity of chalcidid wasps (Hymenoptera: Chalcididae) in natural and man-made agroecosystems of Chhattisgarh, India

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ABSTRACT: The present study was aimed to document and compare the diversity of chalcidid wasps (Hymenoptera: Chalcididae) in the natural ecosystems and man-made agroecosystems of Chhattisgarh, India. Sweep net and yellow pan traps were used for sampling and a total of 354 individuals belonging to 70 species, 11 genera and four subfamilies of Chalcididae were collected in the last five years i.e. between 2019 – 2023 and studied. About 156 individuals were reported from the collections of 2019 – 2020 that belonged to 42 species of 10 genera under four subfamilies from the two different ecosystems whereas 198 specimens belonging to 56 species, nine genera and 4 subfamilies were recorded from Chhattisgarh's two different ecosystems in 2021 – 2023. The natural ecosystems of Chhattisgarh stood out as the rich Chalcididae diverse areas throughout the study periods.

KEYWORDS: Agroecosystems, natural ecosystems, Chalcididae, diversity

INTRODUCTION

India is considered as a megadiverse nation because of its vast diversity of flora and fauna (Roy and Roy, 2015). It is based at the triad junction of the Indo-Malayan, Afrotropical and Palearctic realms because of which the rich biological diversity has been encouraged (Newton and Dale 2001). India has 10 biogeography zones including twenty-four provinces of biota (Rodgers and Panwar 1990; Rodgers *et al*. 2000) and four biodiversity hotspots (Myers *et al.* 2000). Chhattisgarh is one such state which comes in the Chota Nagpur province of Deccan Peninsula biogeography zone. The state possesses a rich biodiversity with around 44% of its area under forest cover. Three different agroclimatic zones namely the Northern Hills zone (28.0%), the Chhattisgarh Plains zone (51.0%) and the Bastar Plateaus zone (21.0%) are found in Chhattisgarh (Anonymous, 2019). Very few studies have been conducted to study and document any arthropod (insect) fauna of Chhattisgarh.

Chalcidoidea is a tremendous diverse superfamily of Apocrita suborder (Hymenoptera) comprising of 23 families (Heraty *et al*., 2013; Askew and Mifsud, 2016). Members of the family Chalcididae are easily noticeable due to the presence of numerous teeth on the ventral edge of their enlarged hind femora, strong punctation of the thorax and a sharp posterior carina bordering the gena (Narendran and van Achterberg, 2016). Members of Chalcididae often parasitize on various other insects, mainly in their pupae (Narendran and van Achterberg, 2016). The family currently includes 87 genera and 1,464 species placed in five subfamilies namely Chalcidinae, Dirhininae, Epitraninae, Haltichellinae and Smicromorphinae. Although taxonomic studies on Indian Chalcididae (Narendran, 1989) are available but such an enormous study to document and compare Chalcididae diversity with respect to its natural ecosystem and agroecosystem habitats in Chhattisgarh state has not been done before.

MATERIALS AND METHODS

Extensive surveys were undertaken and the last five years i.e. from 2019 – 2023 were considered to document chalcidid wasps from the three different agro-climatic zones of Chhattisgarh state. Rigorous collections were done from different agriculture college farms, KVKs, wildlife sanctuaries and National Park, etc. Permission to collect samples was accorded from the Fig. 1. Office of the Principal Chief Conservator of Forests (Wildlife Management & Bio-diversity Conservation cum-Chief Wildlife Warden) Chhattisgarh via letter no. 4369 and 806, dated 30/11/2021 and 17/02/2023, respectively.

Sweep net and yellow pan traps were used to collect the samples. The sampling was done by laying 100 Moericke traps at each site generally for a period of one week. The obtained samples were transferred to a container having 70% alcohol. After being killed, the chalcidid wasps were brought to lab; curated, labelled and secured in fumigated insect boxes. Specimens were later on examined under a Leica MZ16A stereo – zoom microscope and identified up to the species level using

Joseph *et al*. (1973), Bouček and Narendran (1981), Narendran (1989), Narendran & van Achterberg (2016) and others. The identified specimens have been deposited in the National Insect Museum (NIM) of ICAR- National Bureau of Agricultural Insect Resources, Bangalore, India.

Statistical analysis

Alpha or species diversity of each site was estimated using the following ecological indices: -

- **Simpson's Diversity Index (SDI) = 1-D** where D = Simpson's Index.
- **Simpson's Index (D) = *Σ*n (n-1) / N(N-1)** where n = number of a species' individuals and N = total number of all species' individuals.

Simpson's Diversity Index is given by subtracting the value of Simpson's index from 1. The index value varies from 0 to 1, with 1 representing infinite diversity and 0 representing no diversity, respectively. SDI is a diversity measure which takes into consideration both the number of species present and the relative abundance of each species (Simpson, 1949).

- **Shannon-Wiener index (H') = – *Σ*Pi ln (Pi)** where Pi = S / N; S = number of a species' individuals, N = total number of all species' individuals, ln = logarithm to base e. The greater the value of H', the higher the diversity (Shannon and Wiener, 1949).
- **Margalef index α = (S – 1) / ln (N)** where S = total number of species, N = total number of all species' individuals (Margalef, 1958).
- **Pielou's Evenness Index E1 = H' / ln (S)** where H' = Shannon-Wiener diversity index, S = total number of species in the sample (Pielou, 1966). As species richness and evenness increase, diversity also increases (Magurran, 1988).

RESULTS AND DISCUSSION

A total of 354 specimens belonging to eleven genera under four subfamilies and 70 species were examined during the study period. The chalcidid wasps belonged to Chalcidinae, Dirhininae, Epitraninae and Haltichellinae subfamilies. The subfamily Haltichellinae (n = 226, 64.0%) with 41 species under 7 genera was the most abundant followed by subfamily Dirhininae (n = 69, 19.0%) subfamily Chalcidinae (n = 46, 13.0%) with 16 species in one genus and Epitraninae (n = 13, 4.0%) represented by 5 species under one genus. In the year 2019-2020, the genera *Antrocephalus* Kirby, *Brachymeria* Westwood, *Dirhinus* Dalman, *Haltichella* Spinola, *Hockeria* Walker, *Kriechbaumerella* Dalla Torre and *Psilochalcis* Kieffer were recorded from both the ecosystems and can be considered as the generalists (Table 1). In the year 2019 – 2020, Chalcidid wasp's genus *Brachymeria* Westwood, *Dirhinus* Dalman and *Kriechbaumerella* Dalla Torre were the most speciose with 4 species each in the natural ecosystems;

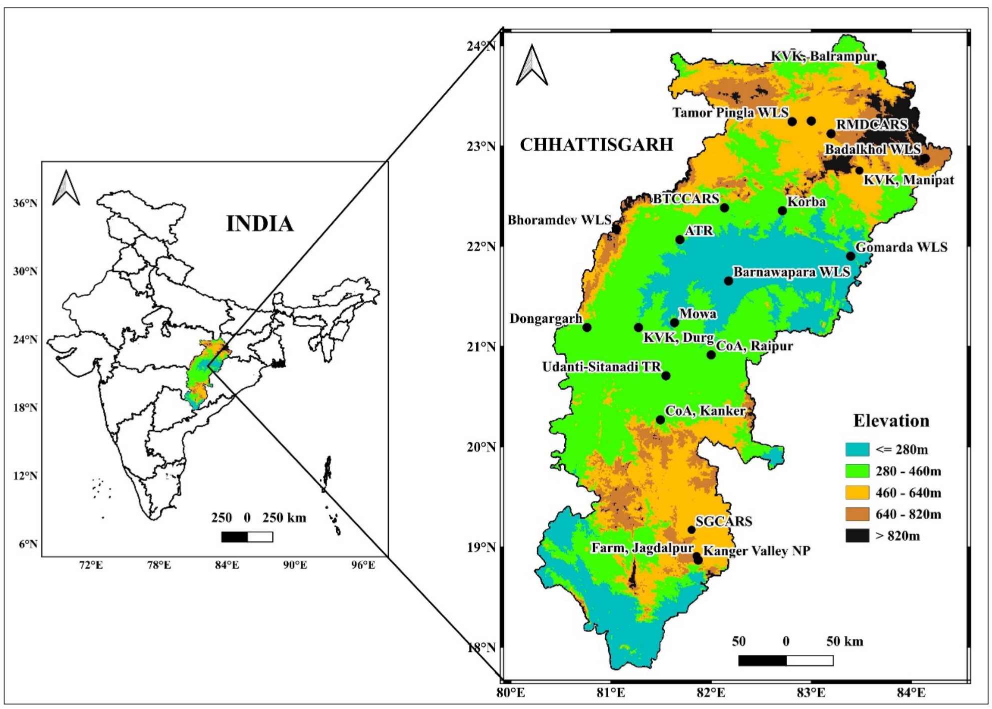

Fig.1. Map showing sites of sample collections

Table 1. Abundance, richness and relative frequency of chalcidid wasps (Hymenoptera: Chalcididae) species collected in natural and man-made agroecosystems of Chhattisgarh, India

S. No.	Species	2019 – 20						2021 – 23					
		Natural ecosystem		Agro -ecosystem		Total		Natural ecosystem		Agro -ecosystem		Total	
		Abundance	Relative frequency (%)	Abundance	Relative frequency (%)	Abundance	Relative frequency (%)	Abundance	Relative frequency (%)	Abundance	Relative frequency (%)	Abundance	Relative frequency (%)
1.	*Brachymeria apicornis* Cameron, 1911	0	0.00	0	0.00	0	0.00	1	1.52	4	3.05	5	2.54
2.	*Brachymeria banksi* Ashmead, 1905	0	0.00	4	3.70	4	2.55	0	0.00	2	1.53	2	1.02
3.	*Brachymeria bengalensis* Cameron, 1897	0	0.00	1	0.93	1	0.64	1	1.52	1	0.76	2	1.01
4.	*Brachymeria burksi* Chhotani, 1966	2	4.08	0	0.00	2	1.27	0	0.00	0	0.00	0	0.00
5.	*Brachymeria euploea* Westwood, 1837	6	12.24	1	0.93	7	4.46	1	1.52	3	2.27	4	2.02
6.	*Brachymeria fulvitarsis* Cameron, 1906	0	0.00	1	0.93	1	0.64	0	0.00	1	0.76	1	0.51
7.	*Brachymeria hattoriae* Habu, 1961	1	2.04	0	0.00	1	0.64	0	0.00	0	0.00	0	0.00
8.	*Brachymeria jambolana* Gahan, 1942	1	2.04	1	0.93	2	1.27	2	3.03	0	0.00	2	1.02

9.	*Brachymeria jayaraji* Joseph, Narendran and Joy, 1972	0	0.00	1	0.93	1	0.64	0	0.00	0	0.00	0	0.00
10.	*Brachymeria lugubris* Walker, 1871	0	0.00	4	3.70	4	2.55	0	0.00	0	0.00	0	0.00
11.	*Brachymeria manjerica* Narendran, 1989	0	0.00	1	0.93	1	0.64	0	0.00	0	0.00	0	0.00
12.	*Brachymeria megaspila* Cameron, 1907	0	0.00	0	0.00	0	0.00	0	0.00	2	1.53	2	1.02
13.	*Brachymeria nephantidis* Gahan, 1930	0	0.00	1	0.93	1	0.64	0	0.00	1	0.76	1	0.51
14..	*Brachymeria podagrica* Fabricius, 1787	0	0.00	0	0.00	0	0.00	1	1.52	0	0.00	1	0.51
15.	*Brachymeria rufescens* Cameron, 1906	0	0.00	0	0.00	0	0.00	0	0.00	1	0.76	1	0.51
16.	*Brachymeria wiebsina* Joseph, Narendran and Joy, 1972	0	0.00	0	0.00	0	0.00	0	0.00	1	0.76	1	0.51
17.	*Dirhinus anthracia* Walker, 1846	0	0.00	3	2.78	3	1.91	3	4.55	15	11.45	18	9.14
18.	*Dirhinus auratus* Ashmead, 1905	7	14.29	8	7.41	15	9.55	0	0.00	8	6.11	8	4.06
19.	*Dirhinus bakeri* Crawford, 1915	0	0.00	0	0.00	0	0.00	0	0.00	1	0.76	1	0.51

20.	*Dirhinus banksi* Rohwer, 1923	0	0.00	0	0.00	0	0.00	0	0.00	1	0.76	1	0.51
21.	*Dirhinus claviger* Bouček and Narendran, 1981	1	2.04	2	1.85	3	1.91	0	0.00	2	1.53	2	1.02
22.	*Dirhinus deplanatus* Bouček and Narendran, 1981	1	2.04	0	0.00	1	0.64	0	0.00	0	0.00	0	0.00
23.	*Dirhinus himalayanus* Westwood, 1836	7	14.29	6	5.56	13	8.28	0	0.00	2	1.53	2	1.02
24.	*Eniacomorpha madagascariensis* Masi, 1947	1	2.04	1	0.93	2	1.27	0	0.00	0	0.00	0	0.00
25.	*Epitranus albipennis* Walker, 1874	0	0.00	0	0.00	0	0.00	1	1.52	0	0.00	1	0.51
26.	*Epitranus crassicornis* Bouček, 1982	1	2.04	0	0.00	1	0.64	0	0.00	0	0.00	0	0.00
27.	*Epitranus elongatulus* Motschulsky, 1863	0	0.00	0	0.00	0	0.00	0	0.00	1	0.76	1	0.51
28.	*Epitranus erythrogaster* Cameron, 1888	0	0.00	0	0.00	0	0.00	3	4.55	6	4.58	9	4.57
29.	*Epitranus indicus* Husain and Agarwal, 1982	0	0.00	0	0.00	0	0.00	0	0.00	1	0.76	1	0.51
30.	*Antrocephalus cariniaspis* Cameron, 1911	0	0.00	0	0.00	0	0.00	0	0.00	1	0.76	1	0.51

31.	*Antrocephalus cariniceps* Cameron, 1911	4	8.16	16	14.81	20	12.74	1	1.52	10	7.63	11	5.58
32.	*Antrocephalus dividens* Walker, 1860	0	0.00	0	0.00	0	0.00	0	0.00	3	2.29	3	1.52
33.	*Antrocephalus hakonensis* Ashmead, 1904	0	0.00	0	0.00	0	0.00	0	0.00	3	2.29	3	1.52
34.	*Antrocephalus indicus* Husain and Agarwal, 1982	0	0.00	1	0.93	1	0.64	0	0.00	0	0.00	0	0.00
35.	*Antrocephalus japonicus* Masi, 1936	0	0.00	5	4.63	5	3.18	1	1.52	5	3.82	6	3.05
36.	*Antrocephalus mitys* Walker, 1846	0	0.00	0	0.00	0	0.00	0	0.00	1	0.76	1	0.51
37.	*Antrocephalus nasutus* Holmgren, 1868	0	0.00	0	0.00	0	0.00	1	1.52	0	0.00	1	0.51
38.	*Antrocephalus niger* Masi, 1929	0	0.00	1	0.93	1	0.64	2	3.03	7	5.34	9	4.57
39.	*Antrocephalus peechiensis* Narendran, 1989	0	0.00	0	0.00	0	0.00	1	1.52	0	0.00	1	0.51
40.	*Antrocephalus phaeospilus* Waterston, 1922	0	0.00	1	0.93	1	0.64	5	7.58	2	1.53	7	3.55
41.	*Antrocephalus sepyra* Walker, 1846	3	6.12	9	8.33	12	7.64	0	0.00	1	0.76	1	0.51

42.	*Antrocephalus validicornis* Holmgren, 1868	0	0.00	6	5.56	6	3.82	10	15.15	8	6.11	18	9.14
43.	*Haltichella clavicornis* Ashmead, 1904	0	0.00	1	0.93	1	0.64	1	1.52	0	0.00	1	0.51
44.	*Haltichella delhensis* Roy and Farooqi, 1984	0	0.00	1	0.93	1	0.64	0	0.00	2	1.53	2	1.02
45.	*Haltichella luzonica* Narendran, 1989	2	4.08	7	6.48	9	5.73	4	6.06	4	3.05	8	4.06
46.	*Haltichella macrocera* Waterston, 1922	0	0.00	0	0.00	0	0.00	2	3.03	0	0.00	2	1.02
47.	*Hockeria ammioshimensis* Habu, 1960	0	0.00	0	0.00	0	0.00	0	0.00	1	0.76	1	0.51
48.	*Hockeria anupama* Narendran, 1989	0	0.00	1	0.93	1	0.64	0	0.00	0	0.00	0	0.00
49.	*Hockeria assamensis* Narendran, 1989	2	4.08	5	4.63	7	4.46	3	4.55	3	2.29	6	3.05
50.	*Hockeria atra* Masi, 1929	0	0.00	0	0.00	0	0.00	1	1.52	0	0.00	1	0.51
51.	*Hockeria bifasciata* Walker, 1834	0	0.00	1	0.93	1	0.64	0	0.00	0	0.00	0	0.00
52.	*Hockeria guptai* Narendran, 1989	0	0.00	0	0.00	0	0.00	0	0.00	1	0.76	1	0.51
53.	*Hockeria hayati* Narendran, 1989	0	0.00	0	0.00	0	0.00	0	0.00	3	2.29	3	1.52

54.	*Hockeria menoni* Narendran, 1986	0	0.00	0	0.00	0	0.00	0	0.00	1	0.76	1	0.51
55.	*Hockeria polycarinata* Narendran, 1989	0	0.00	0	0.00	0	0.00	2	3.03	1	0.76	3	1.52
56.	*Hockeria tristis* Strand, 1911	0	0.00	0	0.00	0	0.00	1	1.52	0	0.00	1	0.51
57.	*Kriechbaumerella gibsoni* Narendran, 1989	1	2.04	0	0.00	1	0.64	0	0.00	0	0.00	0	0.00
58.	*Kriechbaumerella kraussi* Narendran, 1989	1	2.04	4	3.70	5	3.18	1	1.52	1	0.76	2	1.02
59.	*Kriechbaumerella nepalensis* Narendran, 1989	0	0.00	1	0.93	1	0.64	2	3.03	5	3.82	7	3.55
60.	*Kriechbaumerella ornatipennis* Cameron, 1902	0	0.00	3	2.78	3	1.91	3	4.55	2	1.53	5	2.54
61.	*Kriechbaumerella pulvinata* Masi, 1932	4	8.16	3	2.78	7	4.46	0	0.00	4	3.05	4	2.03
62.	*Kriechbaumerella rufimanus* Walker, 1860	2	4.08	2	1.85	4	2.55	2	3.03	5	3.82	7	3.55
63.	*Kriechbaumerella titusi* Narendran, 1989	0	0.00	2	1.85	2	1.27	0	0.00	0	0.00	0	0.00
64.	*Lasiochalcidia dargelasii* Latreille, 1805	1	2.04	0	0.00	1	0.64	0	0.00	0	0.00	0	0.00
65.	*Proconura caryobori* Hanna, 1934	0	0.00	0	0.00	0	0.00	1	1.52	0	0.00	1	0.51

66.	*Psilochalcis adhara* Narendran, 1989	0	0.00	0	0.00	0	0.00	1	1.49	0	0.00	1	0.51
67.	*Psilochalcis carinigena* Cameron, 1907	0	0.00	1	0.93	1	0.64	1	1.52	4	3.05	5	2.54
68.	*Psilochalcis crasssicornis* Masi, 1929	0	0.00	0	0.00	0	0.00	1	1.52	0	0.00	1	0.51
69.	*Psilochalcis soudanensis* Steffan, 1951	0	0.00	1	0.93	1	0.64	5	7.58	0	0.00	5	2.54
70.	*Psilochalcis subarmata* Foerster, 1855	1	2.04	1	0.93	2	1.27	1	1.52	1	0.76	2	1.02
	Total individuals	**49**		**108**		**157**		**66**		**132**		**198**	
	Species richness	**20**		**36**		**42**		**32**		**43**		**56**	

Brachymeria Westwood was the most speciose with 9 species in the agroecosystems. In the year 2021 – 2023, *Antrocephalus* Kirby was the most speciose with 7 species in the natural ecosystems and 10 species in the agroecosystems. *Dirhinus himalayanus* Westwood and *Dirhinus auratus* Ashmead were the most abundant species in natural ecosystems (n = 7; 14.29%) whereas *Antrocephalus cariniceps* Cameron was the most abundant species in agroecosystems, (n = 16; 14.81%) in the year 2019 – 2020. *Antrocephalus validicornis* Holmgren was the most abundant species in natural ecosystems (n = 10; 15.15%) whereas *Dirhinus anthracia* Walker was the most abundant species in agroecosystems (n = 15; 11.45%) in the year 2021 – 2023 (Table 1).

Out of 354 examined specimens, 156 specimens were reported from the collections of 2019 – 2020 that belonged to 42 species of 10 genera under 4 subfamilies from the two different ecosystems whereas 198 specimens belonging to 56 species, 9 genera and 4 subfamilies were recorded from Chhattisgarh's two different ecosystems in 2021 – 2023. In 2019 – 2020, comparatively higher species diversity and low abundance of Chalcididae was observed in the natural ecosystems (H' = 2.71, α = 4.88) whereas agroecosystems (H' = 1.71, α = 7.48) had low species diversity and higher abundance. In the natural ecosystems, comparatively higher species diversity and low abundance (H' = 0.78, α = 7.40) was observed than the agroecosystems (H' = 0.63, α = 8.62) that had low species diversity and higher abundance in 2021 – 2023 collections. Chalcididae species was comparatively more abundant and evenly distributed in natural ecosystems (SDI = 0.94, E1 = 0.90) than agroecosystems (SDI = 0.95, E1 = 0.48) that was less abundant and unevenly distributed in 2019 – 2020. During 2021 – 2023, Chalcididae species was comparatively more abundant and evenly distributed in natural ecosystems (SDI = 0.96, E1 = 0.22) and less abundant and unevenly distributed in agroecosystems (SDI = 0.96, E1 = 0.17).

CONCLUSION

Because of the many strata between the ground and canopy, the structural variability of forest stands provides a vast number of ecological niches that support species diversity and structural richness has a significant impact on forest biodiversity. Similar research on Chalcididae from the state has also demonstrated that, in comparison to natural ecosystems, chalcidid wasps diversity is often lower in agroecosystems (Alisha et al. 2020). This study emphasizes the importance of the forest ecosystems for chalcidid wasps as well as the lack of studies on Chalcididae documentation across different ecosystem and habitats in the Central region of India. Further studies should be encouraged in the country to document and improve our knowledge of Chalcididae diversity and distribution. More data and information on chalcidid wasps will enable us to use them as potential biological control agents in Integrated Pest Management strategies for agroecosystems.

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