REVIEW OF LITERATURE
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3.1 Encyrtidae Taxonomy

World

Taxonomy of Chalcid started in the middle of 18th century. Latrielle 1809, laid the foundation of encyrtid taxonomy by describing several species of genus Encyrtus. Walker (1837) created family name Encyrtidae on the basis of genus Encyrtus, which he credited to Dalman (1820) instead of Latrielle (1809). Westwood (1840), kept encyrtids under 'Encyrtides' as one of its subfamilies of his family Chalcididae. He attributed 17 genera under 'Encyrtides'. In this subfamily he included some genera belonging to families: Aphelinidae, Trichogrammatidae and Euplemidae of today. He also, like Walker, recognized Dalman as author of genus Encyrtus. Foerster (1856) renamed the family as 'Encyrtoidae' while describing twelve new genera. He was first worker who laid down certain characters for the family.

Mayr (1876) gave detailed description of 25 genera (9 new) and 108 species. The Swedish entomologist Thomson (1876) studied 24 genera (8 new) and 81 species. In 1878 he demoted the family to the rank of tribe Encyrtini and assigned it under the family Pteromalidae. Howard (1881, 1885) followed Westwood (1840) and placed encyrtids in the subfamily Encyrtinae of family Chalcididae. Aurivillius (1888) described the genus Arrhenophagus and kept it under 'Encyrtiderna' (=Encyrtides). Ashmead (1899), for the first time placed encyrtids in the family Encyrtidae and Chalcidooids under the super family Chalcidoidea. He further divided family Encyrtidae into three subfamilies, namely, Eupelminae, Encyrtinae (equivalent to 'Encyrtoidae' of Foerster) and Signiphorinae. In 1900 he further split the subfamily Encyrtinae into four tribes: Encyrtini, Ectromini, Mirini and Arrhenophagini based on mandibular dentition, number of tarsal segments, condition of hypopygium (subgenital plate), and antennae location on head, and number of spurs on hind tibia. He (1904) described 90 genera of encyrtids from European and American fauna and framed a key for them.

Schmideknecht (1909) again demoted chalcids to the rank of a family like Howard (1881), and considered encyrtids and eupelmids as distinct subfamilies of Chalcididae. He further in 1930 subdivided the subfamily Encyrtinae into three tribes: Encyrtini, Ectromini and Mirini. Girault (1915a) included five subfamilies: Encyrtinae,
Eupelminae, Signiphorinae, Aphelininae and Tanaostigminae under the family Encyrtidae. He further split the subfamily Encyrtinae into five tribes: Encyrtini, Ectromini, Eucomyni, Amirini and Arrhenophagini. He also described several genera and species under Encyrtinae and raised Ashmead's (1904) tribe Tonaostigmini to subfamily rank Tonaostigminae. Mercet (1921) gave Spanish Fauna, he did not approve Ashmead's (1900) as well as Girault's (1915a) classification. He excluded the subfamilies: Eupelminae, Signiphorinae, Aphelininae and Tanaostigminae from the family Encyrtidae and divided it into two subfamilies namely a) Arrenophaginos (with single genus *Arrhenophagus*) and b) Encirtinos containing 92 genera accommodated in 12 groups. This division was based mainly on the antennal characters, venation of forewing and number of tarsal segments. In 1922b he proposed a subfamily Antheminae for genus *Anthemus* Howard which was placed by Howard (1896) in the family Mymaridae. Ishii (1928) worked on Encyrtinae- fauna of Japan. He adopted similar pattern as proposed by Ashmead (1900) subdivided Encyrtinae into three tribes - Mirini, Ectromini and Encyrtini.

Compere (1928, 31b, 37, 38, 39, 40a, 47, 57, 60 and 61) mainly worked on African Encyrtidae. In 1951, Risbec described 24 genera and 47 species of Encyrtidae from Madagascar. Nikolskaya (1952) discarded Ashmead’s (1900), Girault’s (1915) and Mercet’s (1921) system of dividing the family Encyrtidae into subfamilies and tribes. She gave 109 genera and 343 species from U.S.S.R. Besides adding information on distribution and host, she also gave a good account of diagnostic generic characters followed by practical key to the species.

Ferriere (1953) divided family Encyrtidae into four subfamilies Encyrtinae, Antheminae, Arrhenopaginiae and Signiphorinae on the basis of characters of mandibular dentition, number of tarsal segments, number of funicular joints and venation of forewing. He allocated the genera of Encyrtinae to 15 groups. Erdos & Novicky (1955) adopted three subfamilies of Mercet's classification, but the subfamily Encyrtinae was subdivided into 15 tribes. Division of tribes was mainly based on characters of mandible, antennal funicle and club, wing infuscation and their venation, abdomen, and condition of ovipositor. They provided separate keys for males and females covering 134 genera including 5 new ones.
Hoffer (1955) worked on phylogeny and taxonomy of Encyrtidae and divided the family into three subfamilies: Encyrtinae, Arrhenophaginae and Antheminae. He divided subfamily Encyrtinae into 20 tribes in which 10 tribes were new. He gave detailed characters of tribes and at the same time compared their status with those of Ashmead (1900) and Mercet (1921). Alam (1957) described 15 new species of British genera which spread over 13 genera with reference to coccid hosts and gave emphasis on the utilization of characters of pronotum, subgenital plate, and X-Tergum for generic diagnosis. These generic characters have been upheld by Sugonjaev (1960’, 64’, 68), Trijapitzin (1965b) Agarwal (1965) and Hayat (1969, 1970a & b). Ghesquire (1958a) added a new tribe Psyllacthrini for the new genus *Psyllacthrus* in subfamily Arrhenophaginae. Compere and Annecke (1960) adopted Ashmead’s (1900) and Ishii’s (1928) way of classification and paid attention on characters of paratergites and styli. They agree in dividing the subfamily Encyrtinae into three tribes: Ectromini, Mirini, Encyrtini. Tachikawa (1963) studied Japanese fauna, described 54 genera and 122 species. He followed Mercet (1921) and classified Encyrtidae into Arrhenophaginae and Encyrtinae. He adopted Compere and Annecke (1960) in dividing subfamily Encyrtinae into tribes and maintained same opinion towards Ashmead’s (1900) classification.

De Santis (1963) adopted Hoffer (1955) and Erdos & Novicky (1955) in the classification of the subfamily Encyrtinae. He dealt with 64 genera and 98 species from Argentina; later in 1979 his catalogue was published. Peck (1963) catalogued Nearctic Chalcidoidea. Peck, Boucek and Hoffer (1964) provided practical keys to different families, the one on Encyrtidae covers 141 genera, mainly on the pattern adopted by Ferriere (1953). Kerrich (1964) renamed Ectromini and Mirini as Anagyrini and Bothriothoracini respectively. In 1967 he gave expanded version of the keys provided by Compere and Annecke (1960) and Tachikawa (1963). He further divided the tribe Anagyrini into five subtribes, viz. Anagyrina, Ericydinina, Dinocarsiina and Aphycina, on the basis of X-Tergum, third valvulae, paratergites, punctuation and sclerotization on head. In 1978 he renamed Anagyrini as Tetracnemini. Graham (1969) studied type species described by Dalman, Walker, Westwood, Mayr, Thomson, Mercet, and others. He listed several synonymies and proposed new combinations. Annecke (1964-65, 67, 68, 69, 71 a & b and 77) had important contributions from Ethiopian region.
Annecke and Insely (1971) listed 91 genera and 323 species in their catalogue on encyrtids and aphelinids. Trjapitzin (1973a) formed two subfamilies: Tetracneminae and Encyrtinae under the family Encyrtidae. He (1973b) divided Encyrtinae into 36 tribes. The last 13 tribes were proposed by the author himself. Subfamily level division is depend on - presence or absence of paratergites, margins of linea calva whether differentiated or not, shapes and position of hypopygium, mandibles and their host. Tribal and sub-tribal divisions are depend on mainly following characters: Shape, colour and sculpture of body, dentition of mandibles, venation of forewing, midtibial spur, nature of antenna, whether normal or flattened, presence or absence of parapsidal furrows, biology etc. Trjapitzin and Gordh, (1978 a, b) follow Trjapitzin (1973 a, b) system of dividing the family Encyrtidae into subfamilies, tribes and subtribes. They synonymised the tribes Neocladini with Prionomasticini and proposed 3 new subtribes: Hemaenasiina, Epiencyrtina and Parablastothrichina. The last sub tribal name has already been proposed by Erdos & Novicky (1955:167) in the tribe Microteryni. They reviewed Nearctic Encyrtidae spread over 129 genera and prepared key to the males of 98 genera separately. Noyes (1979) redescribed Howard (1894b, 1897) described 26 species of Encyrtidae from West Indies.

Gordh (1979b) kept Aphelininae and Signiphorinae as subfamilies under Encyrtidae. He listed 112 and 25 genera under Encyrtinae and Tetracneminae respectively. Noyes (1980) described 148 (19 new) genera from Neotropical region. Gordh and Trjapitzin (1981) reviewed several confusing genera and merge tribes Eugahaniini Trjapitzin and Neocladiini Trjapitzin into tribe Prionomasticini Hoffer based on morphological analysis viz. vertex margin, position of toruli, malar space, antennal club, venation of forewing, etc. and host association. Noyes and Hayat (1984) provided key to 263 genera of Encyrtidae (23 new) from Indopacific region. They designated Lectotypes for 44 species; 23genera and 18 species were described as new; one subtribe and one subspecies were raised to tribe and species level respectively. Their work contains 107 generic and 41 specific synonymies and 358 combinations. They adopted the basic classification of sub-families and tribes given by Trjapitzin (1973a, b) but differ on the sub tribal division.
Sharkov (1984 a, b, c, d) revised Encyrtidae genus Eugahania, he resurrected Eugahanini Trjapitzin (1973) which was earlier place by Gordh and Trjapitzin (1981) under Prionomasticini, and considered Neocladiini Trjapitzin as a synonym of it. Boucek's (1988) dealt with revision of genera of 14 families (excluding Encyrtidae, Aphelinidae, Signiphoridae, Trichogrammatidae and Mymaridae) with keys to 550 genera occurring in the Australasian region. New taxa described included 15 subfamilies, 13 tribes, 138 genera and 190 species. 316 generic and 210 specific names were placed in synonymy.

Noyes (1988a) studied 35 genera (4 new) and 67 species (32 new) of Encyrtidae from New Zealand. He provided Keys to both males and females. He adopted Trjapitzin's (1973 a, b) classification pattern of Encyrtidae and suggested urgent revision of it. Trjapitzin’s (1989) formed monograph contains keys to both males and females of 211 genera. He studied 1079 species and also proposed a new tribe Hexencyrtini for the genus *Hexencyrtus* Girault, 1915 and raised subtribe Echthrophyxiellina to the rank of tribe Echthrophyxiellini Hoffer 1954. Subtribe Epiencyrtina Trjapitzin & Gordh, 1978 is regarded as synonym of subtribe Tyndarichina Erdos & Novicky, 1955. He recognized a new genus, 4 new species, 3 generic and 15 specific synonymies, apart from 81 new combinations.

Noyes & Woolley (1994) described 21 genera and 18 species from North America. They gave 14 new generic synonymies, 1 new specific synonymy, 67 new combinations and three replacement. Noyes (2000) studied 26 genera and 147 species belonging to subfamily Tetracneminae from Costa Rica. He recognized 4 new genera, 95 new species and 4 new generic synonymies. He also provided summarized biology and use in biocontrol for every genus and identification keys to the species. In 2002 he gave Interactive Catalogue of world Chalcidoidea. CD-ROM. It is the most important database and provides up to date information on any aspects of chalcids. In 2004 he revised 217 Costa Rican species of *Metaphycus* and eight closely related genera. In 2010 he revised 43 genera and 390 species of Encyrtidae of Costa Rica belonging to the tribes Encyrtini, Echthrophyxiellini, Discodini, Oobiini and Ixodiphagini.

India
Major contributions on taxonomy of Indian chalcid fauna were made by Dalla Torre (1898), Cameron (1913), Waterston (1915) and Ferriere (1961). Cameron (1913) reported encyrtids first time from India. He described a new genus (*Lissencyrtus*) and a species, *clavicornis*, placed doubtfully in *Copidosoma*. Later in 1919 Gahan described a new species (*Aphycus fuscidorsum* = *Metaphycus f.*) with record of some encyrtids. Then no work had been done for several years, Ayyar (1932, 1934) described two species, *Tetracnemus indicus* (now in *Tetracnemoidea*) and *Comperiella indica*. Mani’s (1935) described a new genus and species, *Krishnieriella ceroplastodis* (now in *Anicetus*). Mani’s 1938 Historical catalogue on Chalcidoidea records 16 genera and 19 species of encyrtids. After a gap of about 28 years Agarwal’s (1965) gave descriptions of 17 genera and 22 species. It was first consolidated work on Indian Encyrtidae. Some other contributions to Indian Encyrtidae are: Mani (1935, 39, 41, 89); Narayanan, SubbaRao & Sangwan (1957a); Narayanan, SubbaRao & Mathur (1957b); Narayanan and SubbaRao (1960); SubbaRao (1966, 73, 77); Subba Rao and Rai (1970); Alam (1961, 70); Subba Rao and Hayat (1985 & 86).

Department of Zoology, Aligarh Muslim University has been consistently contributing to this field. Hayat, Alam and Agarwal (1975) dealt with 21 genera and 55 species; Shafee, Alam and Agarwal (1975) included 29 genera and 59 species, Kaul and Agarwal (1985) covered 15 genera and 17 species. These authors follows Mercet (1921, 22) for dividing family Encyrtidae into subfamilies and Annecke (1960), Tachikawa (1963) and Kerrich (1967) for dividing subfamily Encyrtinae into three tribes: Anagyrini, Encyrtini and Bothriothoracini.

(1994) studied 20 genera belonging to the tribe Anagyrini from Oriental region. They also provided biology and biocontrol use for every genus and identification keys to the known Oriental species. Singh & Agarwal (1993a) studied 52 species and 22 genera in detail with their synonymies distribution etc from North Eastern India. Fatima & Shafee (1994) dealt with the taxonomy of the subfamily Encyrtinae. These authors were adopted Alam & Shafee (1981) system of dividing the family Encyrtidae into subfamilies and tribes. Hayat (2006b) gave key for identification of the 106 genera of the Encyrtinae and 37 genera of the Tetracneminae.

3.2 Encyrtidae diversity

Diversity of Encyrtidae in the forest ecosystem has been poorly studied only listing of species of various families of Chalcidoidea is done. Little work has been carried to assess species richness and abundance (biodiversity indices) of Encyrtidae in any ecosystem. Rodríguez et al. (2005) studied diversity of family Encyrtidae collected in the tropical dry forest of the Sierra of Huautla, Morelos. Collections were made using Malaise traps during five days of every month. Eighty two morphospecies were registered. Rodríguez et al. (2009) worked on diversity of Encyrtidae and other families of Hymenoptera, obtained by Malaise traps in the tropical deciduous forest of Huatulco, Oaxaca, Mexico. Collections were carried out during 5 days of every month. The family Encyrtidae was represented by 2 subfamilies, 7 tribes, 9 genera and 17 species. The tribe with the largest number of genera and species was Anagyrini, with 3 genera and 3 species; the remaining tribes were represented by 1 genus and 1 species, respectively. In addition, other 46 families of the order Hymenoptera were collected spread over 2 suborders and 11 super families. The super family with the greatest number of families was Chalcidoidea, the most abundant was Vespoidea. More families were registered during the rainy season; abundance was very similar for both rainy and dry seasons. Rodríguez et al. (2010) studied diversity of family Encyrtidae (parasitoid wasps) of the tropical dry forest of San Javier, Sonora, Mexico. Collections were made using Malaise trapping during 5 days of every month. A total of 52 species, 27 genera and 2 subfamilies were recorded. The subfamily with the largest number of recorded species was
Encyrtinae, with 19 genera and 32 species, followed by Tetracneminae, with 8 genera and 20 species.

Wolda (1987) studied tropical insect diversity relative to altitude. He found out that species richness as well as sample size decreased gradually with increasing altitude over a 100–2200 m range, in contrast to data from the literature which demonstrated a maximum at intermediate elevations. A large perturbation of the environment does, however, decrease species richness of the insect fauna. Melnychuk et al., (2003) studied abundance and diversity of Carabidae (Coleoptera) in different farming systems. Goode et al., (2003) studied Coleopteran families found in disturbed and undisturbed areas in Yucatan, Mexico. A total of 189 insects were collected and identified over a two-week period representing 23 different families. Of the families recorded, 15 were common to both areas. Only 2 families were unique to the agricultural area, and 6 families were unique to the undisturbed forest area. Jones et al., (2008) compared the abundance, diversity, and spatial distribution of the weevil fauna (Coleoptera: Curculionidae) of leaf litter between primary and successional cloud forests at the Biological Reserve Cerro Huitepec in the highlands of Chiapas, Mexico.

Bentz et al., (2005) worked on diversity and abundance of leafhopper species (Homoptera: Cicadellidae) among red maple clones. A total of 45 species from eight different leafhopper subfamilies, for a total of 6055 individuals, were considered in this study. The mean number of leafhoppers collected, mean species richness, diversity and evenness were significantly lower on traps of trees for ‘October Glory’ than for the other clones.

Brehm (2005) studied diversity and community structure of geometrid moths of disturbed habitat in a montane area in the Ecuadorian Andes. Ping et al., (2006) worked on the diversity of moth community in the North Dagang wetland nature reserve, Tianjin, China. A total of 132 moth species were collected, which belonged to 105 genera in 17 families. The data about insects which was collected during the survey was listed and constructed in terms of species-abundance, indices of diversity ($H'$), evenness ($J'$), specific richness ($S$) and individual number ($N$). The results show that moth species in the wetlands were not rich, and the moth community was unstable.
Tan et al. (1990) studied hymenopteran abundance and diversity from three altitudes at Gunung Janing Barat, in Malaysia. Portuondo et al., (2004) studied biodiversity of the order Hymenoptera in the mountain ranges of eastern Cuba. Collections were made using both active and passive methods, which altogether captured more than 20,000 specimens. A total of 714 species were determined, belonging to 416 genera and 42 families, including 47 new records for the country and more than 400 new locality records. The families which yielded the highest numbers of specimens were the Formicidae, Encyrtidae, Scelionidae and Diapriidae; the most diverse ones on the basis of the number of species were the Ichneumonidae, Formicidae, Sphecidae, Apidae and Braconidae. Singh (2010) worked on species diversity of butterfly in the tropical moist deciduous sal habitats of Ankua Reserve forest in Jharkhand, India. He recorded 71 species of butterflies in these forest tracts which revealed high beta diversity.

Greiler et al. (1992) studied species richness and abundance of Chalcidoidea in fallows and cultivated fields using Malaise-trap samples in South West Germany. Guzman et al. (1997) studied diversity and relative abundance of mymarids (Hymenoptera: Chalcidoidea) in central Mexico. Schmitt and Roth (2001) studied the role of parasitoids as indicators of different arable land use types of northeastern Germany. Karlsson et al. (2005) used Malaise traps to find out the species richness of Hymenoptera and Diptera in Sweden. Schowalter and Zhang (2005) studied canopy arthropod assemblages in four overstory and three understory plant species in a mixed-conifer old-growth forest in California. They concluded that the diversity and structure of arthropod communities depended on vegetation structure and/or condition, perhaps as modified by annual variation in weather conditions.

Fontenelle et al. (2000) studied composition and relative abundance of Hymenoptera families in two urban areas of Belo Horizonte, Minas Gerais, Brazil. Marchiori et al., (2003) worked on genera of Braconidae (Hymenoptera) collected in a remnant area of native forest in Itumbiara County; State of Minas Gerais, Brazil, using Malaise traps. The Malaise trap captures the insects by interception. After 24 sample collections, a total of 49 specimens from 19 different genera and 10 subfamilies were obtained. The most frequent genus was Chelomus with 34.7% frequency. March and June were the months of highest occurrence of Braconidae. Restello and Dias (2006) studied
Braconidae diversity (Hymenoptera) from the Unidade de Conservação Teixeira Soares, Marcelino Ramos, Brazil, with emphasis on Microgastrinae. Abreu and Zampieron (2009) collected 712 samples of Hymenoptera with Malaise and Moerick traps in Brazilian savanna belonging to Serra da Canastra National Park. 540 individuals were caught by the Malaise trap and 172 by the Moericke trap. The families Ichneumonidae, Braconidae, and Chacididae presented the biggest abundance with 174 (32%), 112 (21%) and 75 individuals (14%) respectively with the Malaise trap whereas with the Moericke trap the families that presented the greatest abundance were Scelionidae, Platygastridae and Diapridae with 63 (31%), 27 (17%) and 18 individuals (10%) respectively. The Malaise trap was more efficient in the capture of these insects when compared to the Moericke trap. This must have happened probably because of its big efficiency in the flight interception, once these insects are generally well developed for this ability. Another factor to consider was the time exposure of the Moericke trap, though the difference in number of insects captured by the two traps had been fairly significant.

In India most of the work on insect diversity has been done on different orders of insects. Most of Hymenoptera diversity work has been done in various agricultural crops. Pathummal et al. (2000) studied Hymenoptera diversity in single and double cropped rice ecosystem in Kerala. Dey and Raghuraman (2004) monitored hymenopterous parasitoids diversity in rice agro ecosystem. Srinivasa et al. (2004) studied canopy arthropods of Vateria indica L. and Dipterocarpus indicus Bedd. in the rainforests of Western Ghats, South India. The study aimed at quantifying the total arthropod diversity by fogging the rainforest canopies of Vateria indica and Dipterocarpus indicus at Makuta, Western Ghats. Arthropod samples thus obtained were comparable with those from other tropical parts of the world for species richness and diversity. In general, arthropods from D. indicus were more diverse than those from V. indica. Coleoptera tended to be more dominant and hence less diverse in canopies of both trees. The most diverse group in D. indicus was Diptera, while Areneae was the most diverse group in V. indica canopy. The proportion of singletons was extremely high for all the groups, often exceeding 75%. Results suggested that the arthropod composition of the most dominant tree species in the forest could significantly influence the composition of the samples drawn from other tree species in the same forest. Das et al. (2005) studied the changes in Hymenoptera diversity
in organically and conventionally managed tea gardens in W. Bengal. Joseph and Balakrishnan (2005) studied abundance, density and richness of insects in Kazhakuttom Grama Panchayat of Kerala. Chavhan and Pawar (2011) studied distribution and diversity of ant species (Hymenoptera: Formicidae) in and around Amravati city of Maharashtra. During study the dominant genus was *Crematogaster* followed by the genera *Pheidole* and *Camponotus*. Kannagi *et al.*, (2013) studied Hymenoptera diversity in a deciduous forest from South India. The dominant families include Vespidae, Apidae, Formicidae, Sphecidae and Megachilidae, respectively.