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Diversity of parasitic Hymenoptera in three rice-growing tracts of Tamil Nadu, India

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Abstract: Parasitic hymenoptera play a vital role in rice ecosystems as biocontrol agents of pests. Surveys were conducted from August 2015 to January 2016 in three rice growing zones in Tamil Nadu: western zone, Cauvery Delta zone, and high rainfall zone. A total of 3,151 parasitic hymenoptera were collected, of which 1,349 were collected from high rainfall zone, 1,082 from western zone, and 720 from Cauvery Delta zone. Platygastridae, Ichneumonidae, and Braconidae were the most abundant families in all the three zones. The species diversity, richness, evenness as well as beta diversity were computed for all three zones via Simpson's, Shannon-Wiener and Margalef indices. The results showed the high rainfall zone to be the most diverse and the Cauvery Delta zone the least diverse, but with more evenness. Pairwise comparison of zones using Jaccard's index showed 75–79% species similarity.

Keywords: Cauvery Delta, diversity indices, high rainfall, parasitoids.

ஆய்வுச்சுருக்கம்: ஹைமினோப்டிரா ஒட்டுண்ணிகளானது நெல் செடியைத்தாக்கும் பூச்சிகளை கட்டுப்படுத்த மிகவும் உதவுகின்றது. தமிழ் நாட்டில் 2015 ஆம் ஆண்டு ஆகஸ்ட் மாதம் முதல் 2016 ஆம் ஆண்டு ஜனவரி மாதம் வரை ஹைமினோப்டிரா ஒட்டுண்ணிகளுக்கான கணக்கெடுப்பு மூன்று மண்டலங்களில் நடத்தப்பட்டது, அவையாவன மேற்கு மண்டலம், காவேரி டெல்டா மண்டலம் மற்றும் மழைமிகு மண்டலம். இந்த கணக்கெடுப்பின் மூலம் மொத்தம் 3151 ஒட்டுண்ணிகள் அகப்பட்டன. இவற்றுள் 1349 ஒட்டுண்ணிகள் மழைமிகு மண்டலத்திலிருந்தும், 1082 ஒட்டுண்ணிகள் மேற்கு மண்டலத்திலிருந்தும், 720 ஒட்டுண்ணிகள் காவேரி டெல்டா மண்டலத்திலிருந்தும் பிடிப்பட்டன. ஓட்டுண்ணி குடும்பங்களான பிளாட்டிகேஸ்டிரிடே, இக்கினிமோனிடே, பிரக்கோனிடே ஆகியவை அனைத்து மணிடலங்களிலும் இருந்து அதிக அளவில் பிடிப்பட்டன. பன்முகத்தன்மை குறியீடுகளான சிம்ப்ஸன்ஸ், ஷெணான் மற்றும் மார்கலெப் குறியீடுகள் கணக்கிடப்பட்டு மழைமிகு மண்டலத்திலேயே அதிக பல்லுயிர் பெருக்கம் இருப்பதாக கண்டறியப்பட்டது. மிக குறைந்த பல்லுயிர் பெருக்கம் காவேரி டெல்டா மண்டலத்தில் இருப்பதாக தெரியப்பட்டது.

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Author details: Dr. J. Alfred Daniel did his PhD on the diversity of parasitic hymenopterans and currently working as a Senior Research Fellow in the Insect Museum of Tamil Nadu Agricultural University, Coimbatore. Dr. K. Ramaraju is a mite taxonomist and now working as a professor of Entomology in Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore.

Author contribution: JAD involved in the collection of insects, segregation of collected insects up to family level, performed statistical analysis, and wrote the manuscript. KR involved in correction of the manuscript and he is the advisor of the whole study.

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INTRODUCTION

Rice fields harbor a rich and varied fauna compared to other agricultural areas (Heckman 1979; Fritz et al. 2011), which is dominated by arthropods. Communities of terrestrial arthropods in rice fields include pests and their predators and parasitoids (Heong et al. 1991). Fifty-thousand species of parasitic Hymenoptera have been described, and it is likely that this is a small percent of the total number of species (La-Salle & Gauld 1991). Parasitic Hymenoptera are more susceptible to extinction than phytophagous arthropods, and their loss can have devastating effects on ecological stability and community balance. Recently, biodiversity in agricultural land has received growing attention because it plays a significant role in agro-ecosystem function by keeping the pest populations under check (Jervis et al. 2007).

Most parasitic hymenoptera are keystone species, and their removal can result in a cascade effect (La-Salle & Gauld 1993). Utilization of parasitic Hymenoptera in insect pest management programs can bring high economic returns and support sustainable pest management. Wagge (1991) has pointed out that it is fundamentally important to conserve a large reservoir of parasitic Hymenoptera diversity. Given limited resources, it is necessary to identify groups of high priority for study, and parasitic Hymenoptera are one such group (La Salle & Gauld 1991). This study was conducted to evaluate the diversity of parasitic Hymenoptera in three different rice ecosystem zones.

MATERIALS AND METHODS

Sites of collection

The survey was carried out in rice fields during 2015–16 in three different agro-climatic zones of Tamil Nadu: western zone (District representation: Coimbatore at Paddy Breeding Station, Coimbatore, 427m, 11.007N, 76.937E), Cauvery Delta zone (District representation: Thiruvarur at Krishi Vigyan Kendra, Needamangalam, 26m, 10.774N, 79.412E), and high rainfall zone (District representation: Kanyakumari at Agricultural Research Station, Thirupathisaram, 17m, 8.207N, 77.445E) (Figure 1). Collections were made for 20 consecutive days in each zone to give equal weight and minimize chance variation in collections. In all three places conventional agronomic practices were followed. The time of sampling in each zone was decided by the rice growing season of the zone and the stage of the crop, i.e., 20 days in August–September 2015 in western zone, October–November 2015 in high rainfall zone, and December 2015–January 2016 in Cauvery Delta zone.

Methods of collection

Sweep nets, yellow pan traps at ground level, and yellow pan traps erected at canopy level were deployed continuously for 20 days.

Sweep Net

The net employed for collecting was similar to an ordinary insect net with 673mm mouth diameter and a 1,076mm long aluminum handle (Narendran 2001). The frame can be fitted to one end of a long handle that makes sweeping easy and effective. The net bag was made up of thin cotton cloth, 600mm in length with a rounded bottom. The top of the bag which fits around the frame was made of canvas folded over the frame and sewed in position. Sweeping of vegetation was as random as possible from ground level to the height of the crop. Sweeping was done in early morning and late evening hours for about half an hour per day, which involved 30 sweeps in total each day. One to-and-fro motion of the net was considered as one sweep.

Yellow pan traps kept at ground level

This trap was based on the principle that many insects are attracted to bright yellow colour. Yellow pan traps are shallow bright yellow trays 133 × 195 mm and 48mm deep (Noyes 1982). Twenty yellow pan traps were installed at ground level in each site on the bunds, half-filled with water containing a few drops of commercially available detergent to break the surface tension and a pinch of salt to reduce the rate of evaporation and prevent rotting of trapped insects. The spacing between traps was standardized at 1.5m. The traps were set for a period of 24h (Example: traps set at 10.00h on one day were serviced at 10.00h on the following day).

Yellow pan traps erected canopy level

Yellow pan traps were installed at the crop canopy by means of polyvinyl chloride pipes fitted below, with a screw attachment and were installed in 10 traps per zone in the same fashion as yellow pan traps kept at ground level.

Preservation and identification of the specimens

The parasitoids collected were preserved in 70% ethyl alcohol. The dried specimens were mounted on pointed triangular cards and studied under a Stemi (Zeiss) 2000-C and photographed under Leica M 205-A stereo zoom microscopes and identified up to the

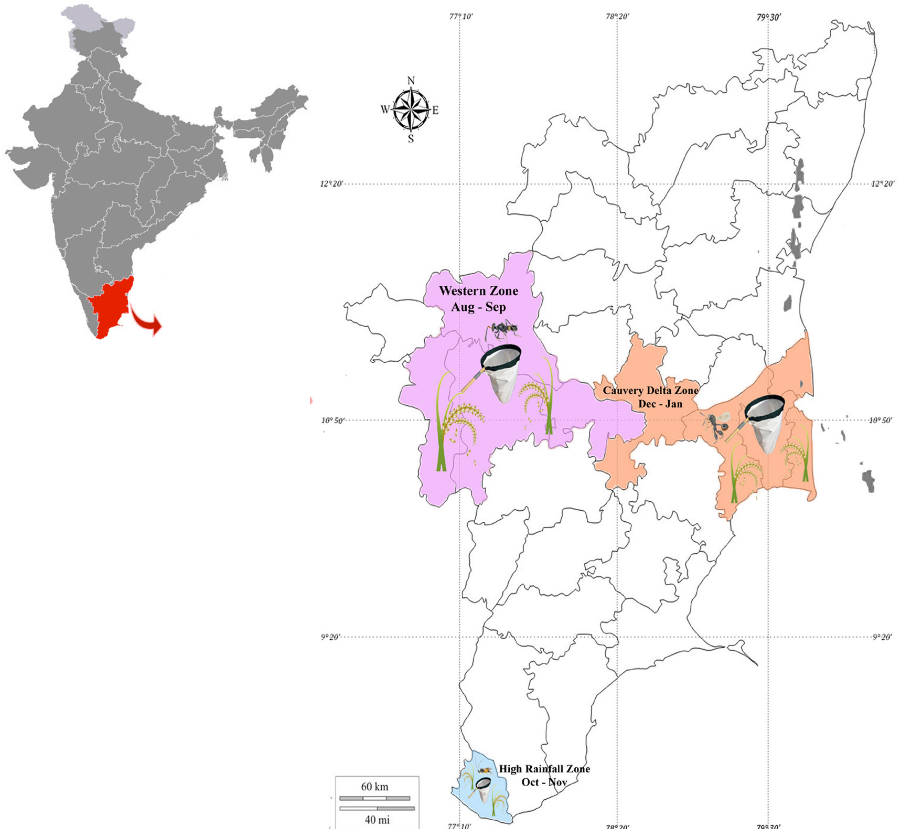

Figure 1. Three zones of collection.

family level through conventional taxonomic techniques following standard keys given by several authors like Narendran (1994), Jonathan (2006), Rajmohana (2006), Sureshan (2008) and "Universal Chalcidoidea Database" developed by Noyes (2017). Further, experts in particular groups of parasitic Hymenoptera were met in person for getting proper identity up to sub family/ genera/ species level wherever possible. Dr. Manickavasagam Sagadai, Sankararaman Hariharakrishnan, Dr. Gowri Prakash James, and Dr. Ayyamperumal Mani (in litt. 9 August 2016) of Annamalai University, Chidambaram, Tamil Nadu helped in identifying Chalcididae, Aphelinidae, Encyrtidae, Megaspilidae, and Dryinidae specimens. Ranjith Avunjikkattu Parambil (in litt. 6 September 2016) from the University of Calicut, Kerala helped in identifying Braconidae, Gasteruptiidae and in overall segregation of all the specimens. Dr. Rajmohana Keloth (in litt. 7 September 2016) from the Zoological Survey of India, Kozhikode, Kerala, helped in identifying Platygastridae, Diapriidae, Proctotrupidae, and Ceraphronidae specimens. Dr. Sureshan Pavittu M. and Dr. Raseena Farzana Vadakkethil Kuttyhassan (in litt. 24 October 2016) from the Zoological Survey of India, Kozhikode, Kerala, helped in identifying Pteromalidae and Torymidae specimes. Dr. Santhosh Shreevihar (in litt. 4 November 2016) from the Malabar Christian College, Kozhikode, Kerala helped in identifying Bethylidae and Eulophidae. Dr. Sudheer Kalathil (in litt. 22 November 2016) from Guruvayurappan College, Kozhikode, Kerala, helped in identifying Ichneumonidae specimens, Dr. P. Girish Kumar (in litt. 30 January 2017) from the Zoological Survey of India, Kozhikode, Kerala, helped in identifying Evaniidae, Eucharitidae, and Scoliidae specimens. Dr. Nikhil Kizhakiyal (in litt. 31 January 2017) from the Zoological Survey of India helped in identifying Eurytomidae specimens. Dr. Rameshkumar Anandan (in litt. 10 February 2017) from the Zoological Survey of India, Kolkata, West Bengal helped in identifying Mymaridae and a few Encyrtidae specimens. Dr. Poorani Janikiraman (in litt. 20 March 2017) from the National Research Centre for Banana, Trichy, Tamil Nadu, helped in identifying a few Eupelmidae specimens. Dr. Gary A.P. Gibson (in litt. 24 March 2017) from the Canadian National Collection of Insects, Arachnids, and Nematodes, Canada, helped in identifying a few Eupelmidae specimens by sending keys through mail. Dr. Arkady Lelej (in litt. 15 April 2017) from the Federal Scientific Center of the East Asia Terrestrial Biodiversity, Vladivostok, Russia, helped in identifying Mutillidae specimens through photographs. Dr. Matthew Buffington (in litt. 16 April 2017) from the United States Department of Agriculture, Washington, D.C. United States helped in identifying Figitidae specimens through photographs. Dr. Lynn Kimsey (in litt. 17 April 2017) from the Bohart Museum of Entomology, University of California, helped in identifying Chrysididae and Tiphiidae specimens through photographs. Nearly, 174 species of parasitoids were collected during the entire study period, however, some of the parasitoids were identified only up to the sub family/ generic level and only a few were identified up to the species level. Identified specimens are deposited at the Insect Biosystematics lab, Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India.

Measurement of diversity

Relative Density

Relative density of the species was calculated by the formula, Relative Density (%) = (Number of individuals of one species / Number of individuals of all species) X 100.

Alpha Diversity

Alpha diversity of the zones was quantified using Simpson's diversity index (SDI), Shannon-Wiener index (H'), Margalef index (α) and Pielou's evenness index (E1).

Simpson's Index

Simpson's diversity index is a measure of diversity which takes into account the number of species present, as well as the relative abundance of each species. It is calculated using the formula, $D = \Sigma n\,(n-1)/\,N(N-1)$; where n = total number of organisms of a particular species and N = total number of organisms of all species (Simpson 1949). Subtracting the value of Simpson's diversity index from 1, gives Simpson's Index of Diversity (SID). The value of the index ranges from 0 to 1, the greater the value the greater the sample diversity.

Shannon-Wiener Index

Shannon-Wiener index (H') is another diversity index and is given as follows: $H' = -\Sigma\, Pi \ln(Pi)$; where Pi = S / N, S = number of individuals of one species, N = total number of all individuals in the sample, ln = logarithm to base e (Shannon & Wiener 1949). The higher the value of H', the higher the diversity.

Margalef Index

Species richness was calculated for the three zones using the Margalef index which is given as Margalef index, $\alpha = (S - 1) / \ln(N)$; where S = total number of species, N = total number of individuals in the sample (Margalef 1958).

Pielou's Evenness Index

Species evenness was calculated using the Pielou's evenness index (E1). 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).

Beta Diversity

Beta diversity is a measure of how different (or similar) ranges of habitats are in terms of the variety of species found in them. The most widely used index for assessment of beta diversity is Jaccard index (JI) (Jaccard 1912), which is calculated using the equation: JI (for two sites) = j / (a+b-j); where j = the number of species common to both sites A and B, a = the number of species in site A, and b = the number of species in site B. We assumed the data to be normally distributed and adopted parametric statistics for comparing the sites.

Statistical analysis

The statistical test ANOVA is also used for significant difference in the collections from three zones. The data on population number were transformed into X+0.5 square root before statistical analysis. The mean individuals caught from three different zones were analyzed by adopting randomized block design (RBD) to find least significant difference (LSD). Critical difference (CD) values were calculated at 5 per cent probability level. All these statistical analyses were done using Microsoft Excel 2016 version and Agres software version 3.01.

RESULTS AND DISCUSSION

Faunal survey of parasitic hymenoptera in rice ecosystems in western zone, Cauvery Delta zone and high rainfall zones of Tamil Nadu revealed that the family richness was maximum (25) in the high rainfall zone, followed by western zone (24), and minimum (19) in Cauvery Delta zone (Table 1). All the families of parasitic hymenoptera collected in the present study along with their presence and absence details were provided in Appendix 1. Apidae, Tiphiidae, and Gasteruptiidae were collected only from the western zone and Chrysididae, Mutiliidae, Megaspilidae, and Eucharitidae were

Table 1. Comparison of parasitoid families collected from three rice growing zones of Tamil Nadu.

Families	Zones						Total			
	Western		Cauvery delta		High rainfall					
	No.	%	No.	%	No.	%	No.	%	F	P
Apidae	1	0.1	0	0.0	0	0.0	1	0.0	1.00	0.37
Bethylidae	4	0.4	2	0.3	7	0.5	13	0.4	1.16	0.32
Dryinidae	2	0.2	5	0.7	1	0.1	8	0.3	0.98	0.37
Chrysididae	0	0.0	0	0.0	1	0.1	1	0.0	1.00	0.37
Mutillidae	0	0.0	0	0.0	3	0.2	3	0.1	1.87	0.16
Scoliidae	1	0.1	0	0.0	2	0.1	3	0.1	0.60	0.55
Tiphiidae	3	0.3	0	0.0	0	0.0	3	0.1	1.00	0.37
Ceraphronidae	15	1.4	11	1.5	41	3.0	67	2.1	5.33	0.00
Megaspilidae	0	0.0	0	0.0	1	0.1	1	0.0	1.00	0.37
Aphelinidae	8	0.7	1	0.1	6	0.4	15	0.5	2.32	0.10
Chalcididae	21	1.9	16	2.2	142	10.5	179	5.7	12.79	0.00
Encyrtidae	2	0.2	8	1.1	7	0.5	17	0.5	1.39	0.25
Eucharitidae	0	0.0	0	0.0	1	0.1	1	0.0	1.00	0.37
Eulophidae	41	3.8	23	3.2	97	7.2	161	5.1	6.89	0.00
Eupelmidae	20	1.8	19	2.6	42	3.1	81	2.6	1.60	0.21
Eurytomidae	31	2.9	19	2.6	67	5.0	117	3.7	2.74	0.07
Mymaridae	15	1.4	41	5.7	36	2.7	92	2.9	3.23	0.04
Pteromalidae	32	3.0	21	2.9	29	2.1	82	2.6	0.31	0.73
Torymidae	4	0.4	0	0.0	6	0.4	10	0.3	0.84	0.43
Trichogrammatidae	59	5.5	27	3.8	22	1.6	108	3.4	1.32	0.27
Figitidae	3	0.3	2	0.3	6	0.4	11	0.3	0.54	0.58
Diapriidae	44	4.1	21	2.9	54	4.0	119	3.8	1.45	0.24
Evaniidae	13	1.2	2	0.3	8	0.6	23	0.7	1.91	0.15
Gasteruptiidae	9	0.8	0	0.0	0	0.0	9	0.3	1.00	0.37
Braconidae	180	16.6	163	22.6	231	17.1	574	18.2	0.58	0.56
Ichneumonidae	218	20.1	159	22.1	227	16.8	604	19.2	0.67	0.51
Platygastridae	314	29.0	129	17.9	288	21.3	731	23.2	4.40	0.01
Proctotrupidae	42	3.9	51	7.1	24	1.8	117	3.7	1.08	0.34
Total No. collected	**1082**	-	**720**	-	**1349**	-	**3151**	-	-	
No. of families	**24**	-	**19**	-	**25**	-	**28**	-		

%—Relative Density | No.—Total number of individuals collected | F—Value | P—Value.

collected only from the high rainfall zone. Scoliidae and Torymidae were collected both form western and high rainfall zones, but not from the Cauvery Delta zone. In the study, a total of 1,349 individuals of parasitic Hymenoptera were collected from the high rainfall zone followed by the western zone (1,082), and the Cauvery Delta zone (720) (Figure 2). In all the three zones, Platygastridae, Ichneumonidae, and Braconidae were the most abundant.

Apart from that, Trichogrammatidae, Diapriidae, Proctotrupidae, Eulophidae, Pteromalidae, Eurytomidae, Chalcididae, Eupelmidae, Ceraphronide, Mymaridae and Evaniidae constituted 5.5, 4.1, 3.9, 3.8, 3.0, 2.9, 1.9, 1.8, 1.4, 1.4, and 1.2 per cent relative density, respectively, in the western zone. Other families, viz., Apidae, Bethylidae, Dryinidae, Scoliidae, Tiphiidae, Aphelinidae, Encyrtidae, Torymidae, Figitidae, and Gasteruptiidae were represented by less than 0.8 per cent.

In Cauvery Delta zone, surprisingly, Braconidae (22.6%) was found to be predominant followed by

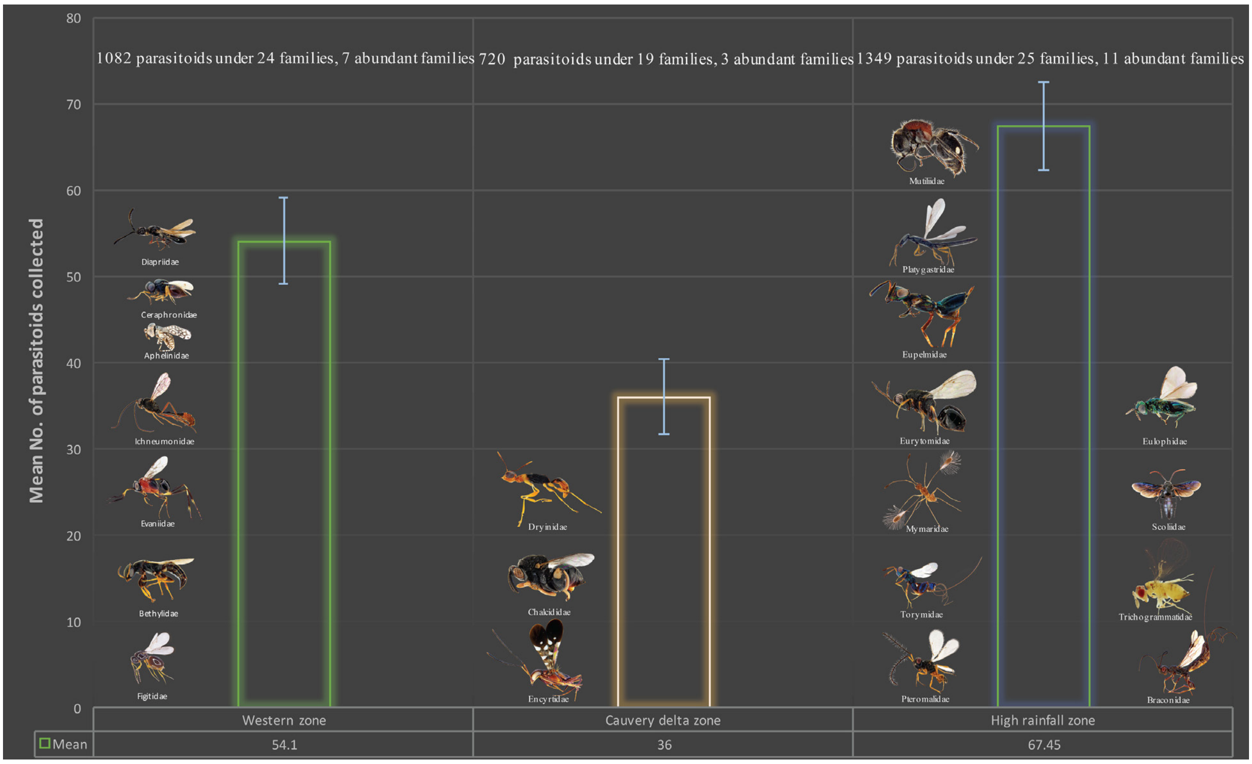

Figure 2. Parasitoids collected under three zones along with the families of abundance.

Table 2. Diversity indices of parasitic hymenoptera from three rice growing zones of Tamil Nadu

Zones	Mean No. of parasitoids collected/day	Std. Error	SID	H´	a	E1	b %
Western	54.10 (7.21)^{b}	±4.95	0.85	0.98	3.29	0.30	W and C -79
Cauvery Delta	36.00 (5.79)^{c}	±4.31	0.83	0.97	2.73	0.33	C and H - 76
High rainfall	67.45 (8.10)^{a}	±5.14	0.87	1.02	3.33	0.31	H and W -75
S.E.D	0.41	-	-	-	-	-	-
CD (p=0.05)	0.84	-	-	-	-	-	-

Figures in parentheses are square root transformed values; In a column, means followed by a common letter(s) are not significantly different by LSD (p=0.05). SID—Simpson's Index of Diversity | H'—Shannon-Wiener Index | a—Margalef index | E1—Pielou's index | b—Beta diversity (Jaccard index). W—Western zone | C—Cauvery Delta zone | H—High rainfall zone.

Ichneumonidae (22.1%) and Platygastridae (17.9%), whereas in the other two zones, Platygastridae was predominant (21.2–29.0 %). Besides these three families, Proctorupidae, Mymaridae, Trichogrammatidae, Eulophidae, Diapriidae, Pteromalidae, Eurytomidae, Eupelmidae, and Chalcididae accounted for 7.1, 5.7, 3.8, 3.2, 2.9, 2.9, 2.6, 2.6 and 2.2 per cent relative densities, respectively. All the other families were represented by less than 1.5 per cent.

In the high rainfall zone, Chalcididae was the fourth most abundant family accounted for 10.5 per cent of total collections, followed by Eulophidae (7.2%), Eurytomidae (5.0%), Diapridae (4.0%), Eupelmidae (3.1%), Ceraphronidae (3.0 %), Mymaridae (2.7%), and Pteromalidae (2.1%). All other families were represented with less than that 1.6 per cent relative density.

A total of 3,151 individuals of parasitic hymenoptera were collected in the present study from the three rice-growing zones of Tamil Nadu. This constitutes 28 families under 11 super families, three super families under Aculeata and eight super families under Parasitica. Platygastridae accounts for 23.2 per cent (Table 1) which was the highest in the collection, followed by Ichneumonidae (19.2%) and Braconidae (18.2%) (Figure 3). These three families constitute more than half, i.e., 60.6 per cent of total collection. Chalcididae was the

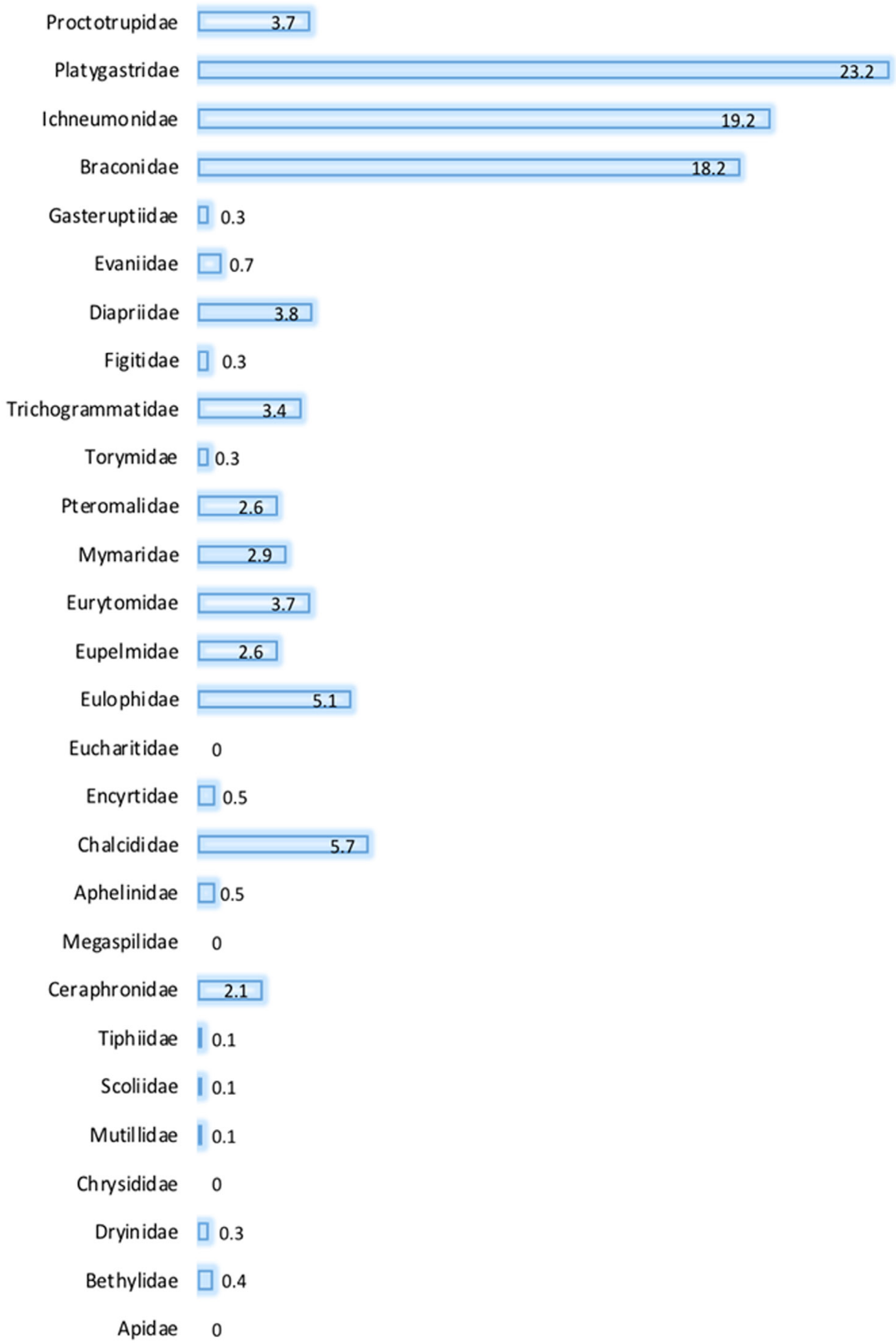

Figure 3. Relative densities of parasitic hymenoptera families from three zones of Tamil Nadu.

fourth most abundant family with 5.7 per cent relative density and Eulophidae constituted 5.3 per cent in the total collections. Diapriidae accounted for 3.8 per cent followed by Proctotrupidae and Eurytomidae with a relative density of 3.7 per cent each. Relative density of 3.4 per cent was constituted by Trichogrammatidae. Families such as Mymaridae, Pteromalidae, Eupelmidae, and Ceraphronidae accounted for 2.9, 2.6, 2.6 and 2.1 per cent, respectively (Figure 3). The other 15 families, viz., Apidae, Bethylidae, Dryinidae, Chrysididae, Mutillidae, Scolidae, Tiphiidae, Megaspilidae, Aphelinidae, Encyrtidae, Eucharitidae, Torymidae, Figitidae, Evaniidae, and Gasteruptiidae accounted for only 3.2 per cent of the total collections.

The ANOVA test results indicated that the P-value for Ceraphronidae, Chalcididae, Eulophidae, Mymaridae, and Platygastridae was less than 0.05, indicating significant difference between the zones for these five families. For all other families the P-value was greater than 0.05, which we consider to be non-significant. A mean of 67.45 ± 5.14 parasitoids per day was collected from high rainfall zone which is found to be statistically significant over other two zones. From the western zone, a mean of 54.10 ± 4.95 parasitoids were collected per day, while that in the Cauvery Delta zone was 36.00 ± 4.31 per day (Figure 2). From the Table 2, it is observed that the Simpson's diversity index ranges between 0.83 to 0.87. Though the index values are pretty much the same for all the three zones, it is the highest for the high rainfall zone (0.87), followed by the western zone (0.85), and the Cauvery Delta zone (0.83). The species composition among elevational zones can indicate how community structure changes with biotic and abiotic environmental pressures (Shmida & Wilson 1985; Condit et al. 2002). Studies on the effect of elevation on species diversity of taxa such as spiders (Sebastian et al. 2005), moths (Axmacher & Fiedler 2008), paper wasps (Kumar et al. 2008), and ants (Smith et al. 2014) reported that species diversity decreased with increase in altitude. According to Janzen (1976), however, diversity of parasitic Hymenoptera is not as proportionately reduced by elevation as in other insect groups, a fact that is in support of our results. A similar study conducted by Shweta & Rajmohana (2016) to assess the diversity of members belonging to the subfamily Scelioninae also declared that the elevation did not have any major effect on the overall diversity patterns. A similar trend was observed for the Shannon-Wiener index (H') and Margalef index (). From the values of Margalef index (a) for the three zones, it was observed that the high rainfall zone was very rich in species with a richness value of 3.33 followed by western zone (3.29) and Cauvery Delta zone (2.73). It is because of the fact that out of 28 families only 19 families were collected from this zone. The Pielou's evenness value (E1) for the sites clearly indicate that the Cauvery Delta zone showed maximum evenness pattern with evenness index value (0.33) followed by high rainfall zone (0.31) and western zone (0.30). The elevational diversity gradient (EDG) in ecology proposes that species richness tends to increase as elevation increases, up to a certain point creating a 'diversity bulge' at moderate elevations (McCain & Grytnes 2010). The elevation dealt with in this work ranged from 17–427 m which was not very high. So taking into account the scale and extent of elevation gradients, it can be said that species diversity and richness did not show any correlation, i.e., species diversity and richness were not proportional with that of elevation.

Altitudinal variation of parasitic Hymenoptera assemblages in an Australian subtropical rainforest was studied by Hall et al. (2015). To detect minute changes in species assemblages, species level sorting is found to give the best result (Grimbacher et al. 2008). The area under cultivation turns out to be a very important factor with respect to abundance and species density in rice fields (Wilby et al. 2006). The number of species in a habitat increases with increase in area (Gotelli & Graves 1996).

Comparison of species similarities using the Jaccard's index between the three sites, taken in pairs showed 79 per cent similarity between the western and Cauvery Delta zones and 76 per cent similarity between the high rainfall and Cauvery Delta zones, and 75 per cent similarity between the high rainfall and western zones.

CONCLUSION

This study reveals the diversity of Hymenoptera parasitoids of three different zones of rice ecosystems of Tamil Nadu, where the the high rainfall zone is the most diverse and the Cauvery Delta zone being the least. The reasons for the significant changes in diversity of parasitoids and their host insects are to be further studied so as to implement pest management strategies and to decide the right biological control tactics to manage pests. As very little is known of parasitic hymenoptera associated with rice ecosystem, this study attempted to enrich the information pertaining to hymenoptera parasitoids associated with rice ecosystems of Tamil Nadu. Thus, this study has generated baseline data which will be much useful for the taking up further in depth studies on Hymenoptera parasitoids of rice ecosystem.

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Appendix 1. List of parasitic hymenopteran families along with their presence and absence details in the three zones of study.

Families	Zones		
	Western	Cauvery Delta	High rainfall
Apidae	P	A	A
Bethylidae	P	P	P
Dryinidae	P	P	P
Chrysididae	A	A	P
Mutillidae	A	A	P
Scoliidae	P	A	P
Tiphiidae	P	A	A
Ceraphronidae	P	P	P
Megaspilidae	A	A	P
Aphelinidae	P	P	P
Chalcididae	P	P	P
Encyrtidae	P	P	P
Eucharitidae	A	A	P
Eulophidae	P	P	P
Eupelmidae	P	P	P
Eurytomidae	P	P	P
Mymaridae	P	P	P
Pteromalidae	P	P	P
Torymidae	P	A	P
Trichogrammatidae	P	P	P
Figitidae	P	P	P
Diapriidae	P	P	P
Evaniidae	P	P	P
Gasteruptiidae	P	A	A
Braconidae	P	P	P
Ichneumonidae	P	P	P
Platygastridae	P	P	P
Proctotrupidae	P	P	P

P—Prensent | A—Absent

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