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Species Diversity and Community Composition of Termites (Isoptera) in Southern Haryana, India

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ABSTRACT

A capturing-identification survey was undertaken to evaluate the termite'sspecies richness and diversity in different study areas (Mahendragarh, Rewari, Nuh, Gurugram, Palwal, and Faridabad) of Southern Haryana, India. A total of 187 samples were collected and identified into 23 species that belong to three families (Termitidae, Rhinotermitidae, Kalotermidae) and four subfamilies viz., Macrotermitinae, Termitinae, Amitermitinae, Coptotermitinae. Species richness varied in respective study areas, i.e., 14, 22, 32, 35. 39 and 45 species were recorded in Faridabad, Rewari, Palwal, Gurugram, Mahendragarh and Nuh respectively. Different diversity indices (Shannon diversity, Simpson diversity, Menhinick diversity, Margalef diversity, Jaccard and Sorensen similarity index) were used to explain diversity of termite fauna. Results reveal that Shannon, Simpson and Margalef Indices were found to be highest in Nuh district and lowest in Faridabad, whereas, Menhinick diversity was highest in Palwal and minimum in Faridabad. However, according to Jaccard and Sorensen similarity Indices, highest species similarity was noticed between Mahendragarh and Rewari showed (0.67, 0.8), while minimum in Faridabad with Gurugram district (0.29, 0.44). Species diversity was also calculated and found to be highest in the month of June, July, August and September in relation to favorable climatic factors as termite required for their survival.

Key words: *Termitidae, Macrotetmitidae, Odontotermes, Diversity indices, Similarity index, Evenness*

Introduction

Nowadays termites have become the most dominant insects due to their competence to support the ecosystem and its eusocial behavior (Collins, 1983; Bong *et al.,* 2012; Paul *et al.,* 2018; Govorushko, 2019). They are reported to enhance microbial growth by sifting soil layers to maintain their chemical nature. Although termites are famous as disparaging pests, destroying buildings and man-made things that indirectly affect financial growth (Akhtar and Sarwar, 1997; Jouquet *et al.,* 2011; Ibrahim and Adebote, 2012). Only subterranean termites themselves can damage 80-90% of total woody things (Su, 1990; Rawat, 2011). They have the potential to degrade cellulosic things in an ecosystem, hence they are also known as the most effective decomposers (Scharf and Tartar, 2008). Since termites community has been influenced by several eco-friendly grades such as rainfall rate, soil water, temperature, fire, altitude, disturbance, and variation in landscapes geology. On average, a greater percentage of the wooden stakes were attacked in summer than winter (Sattar *et al.,* 2013; Ahmed *et al.,* 2018). Its infestations have also been reported in India on different vegetation types (sugarcane, cotton, paddy, maize and veg-

etables) (Parween *et al.*, 2016).

Termites are widely scattered insects and are mostly encountered in tropical and subtropical regions due to a wide range of foraging sites i.e., forests (Collins, 1983; Buczkowski and Bertelsmeier, 2017). The highest termite diversity has also been noticed from Indian; which harbors 300 species denoting about 10% to the total termite diversity listed from all over the world (Krishna *et al.*, 2013; Paul *et al.*, 2018; and Rajmohana *et al.*, 2019).

Initially, only 20 species under 10 genera and 3 families were reported from Haryana. The termite's diversity is also quite abundant in the Kurukshetra University campus as seven species under five genera and two families (Rhinotermitidae, Termitidae) were reported from Kurukshetra University (Kakkar *et al.*, 2015). Currently, 37 species were identified along Haryana belonging to 11 genera (*Odontotermes, Microtermes, Microcerotermes, Heterotermes, Coptotermes, Trinervitermes, Biditermes, Neotermes, Speculitermes, Eremotermes and Angulitermes*) and 3 families (Rhiotermitidae, Kalotermitidae, and Termitidae) (Poonia, 2019). However, only limited information is available on the termite fauna of Haryana. Therefore, due to paucity of data regarding their richness, abundance, and diversity in Haryana state, termite's diversity and its community structure in six districts of Haryana was studied with the help of different diversity indices to compare with other parts of Southern Haryana.

Materials and Methods

Study site

The study was conducted from March, 2020 to November, 2021 in six districts (Mahendragarh, Rewari, Nuh, Gurugram, Palwal and Faridabad) of southern Haryana, India. Southern Haryana is located between 28.25° N and 76.29°E (Fig. 1). A total of 187 termite specimens used in the present study were collected from different locations of Southern Haryana (Table 1). Sampling was carried out using visual exploring of wood, mud galleries, grazing land, urban and rural shelters, forests, and foraging spots in horticultural, agricultural land, and the avenues (Gupta and Kakkar, 2015; Vidyashree *et al.*, 2018; Kasseney *et al.*, 2019). The collected termite specimen was labeled, counted, and well-maintained in glass vials filled with 70% ethyl alcohol and 2-3 drops of glycerin. Details on latitude, the longitude of various collected sampling sites were noted using Global Positioning System.

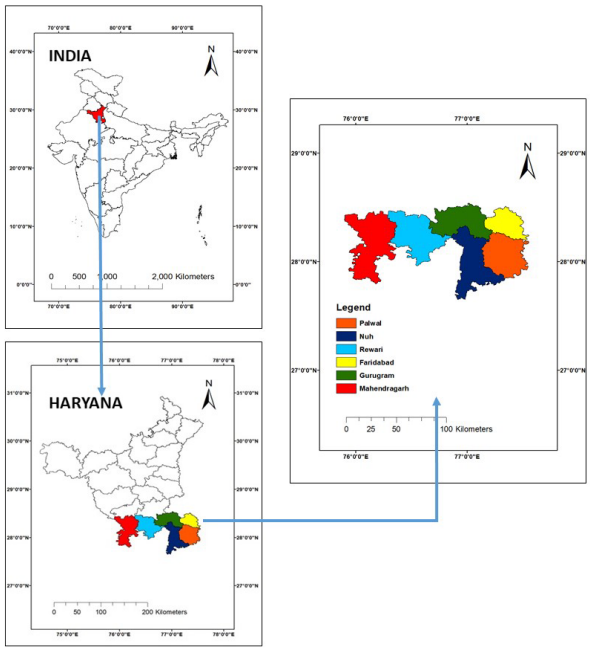

Fig. 1. Study area.

Termite's identification and data analysis

The termites were taxonomically categorized up to species level using the phenotypic keys (Roonwal and Chhotani, 1989; Chottani, 1997; Krishna *et al.*, 2013). Relative abundance related to the number of termite species encountered in each study site was

Table 1. Location of study sites on the map.

Study Area	Co-ordinates	Elevation (m)	Number of samples
Mahendragarh	28°16'9.66'' N & 76°09'9.11'' E.	262 m	39
Rewari	28°112563 N & 76°372053 E	259m	22
Nuh	28°062103 N & 77°002053 E	200 m	45
Gurugram	28°272363 N & 77°012343 E	228 m	35
Palwal	28°082403 N & 77°192313 E	201 m	32
Faridabad	28°242403 N & 77°182473 E	209 m	14

Table 2. Different diversity indices used to assess the isopterans diversity.

Diversity Indices	Formula	Assessed	References
Shannon's Weiner index (H)	$H = -\Sigma^{S}_{i=1}$ pi ln pi	To measures the species diversity within the community of an ecosystem	Vidyashree *et al.*, 2018
Simpson's index(D)	$D= \Sigma p_i^2$	It accounts the number of species present, as well as the relative abundance of each species	Effowe *et al.*, 2021
Margalef's diversity index (d)	d= (S–/)1 ln N	To compare the richness of different study sites over the Simpson index	Vidyashree *et al.*, 2018
Menhinick's index	S/√N	To estimate species richness but at the same time it is independent on the sample size	Vidyashree *et al.*, 2018
Evenness (E)	E= H′ / ln S	To calculate whether species are distributed evenly in the studied area	Hammer *et al.*, 2001
Jaccard's similarity index (Cj)	Cj= a / (a + b + c)	To calculate the similarity index between study sites	Kasseney *et al.*, 2019
Sorensen similarity index (β)	β = 2c/S1+S2	To calculate beta diversity	Ali *et al.*, 2013

calculated. The species diversity and richness of termite fauna were assessed by using Past 3 software (Table 2) (Hammer *et al.*, 2001, Effowe *et al.*, 2021).

Where,

Pi= Proportion of total sample belonging to the i^{th} species

ln = Natural log of the number

S = Number of species or species richness

Ó= Sum from species I to species S

N = the total number of individuals in the sample

H′ = Shannon-Wiener's diversity index

a = number of species common to both the study site,

b = number of the species unique to the first study site

c = the number of the species unique to the second study site.

2 c = Number of bird species common between both transects/study sites

S1 = Number of bird species recorded at transect 1/ site 1

S2 = Number of bird species recorded at transect 2/ site

Results and Discussion

Species Composition

The present study showed theabundance and diversity oftermite species collected from six districts of southern Haryana. A total of 187 samples were identified under 23 species. These species were belonging to eight genera (*Amitermes, Eremotermes, Microcerotermes, Angulitermes, Odontotermes, Microtermes, Neotermes* and *Coptotermes*), 3 family (Termitidae, Kalotermitidae, Rhinotermitidae) and four sub families were recorded (Table 3). From Indian subcontinents, 339 termite species have been reported hence this study reveals about 14.73% of the total termite species reported in Indian subcontinents (Paul *et al.*, 2018; Amina *et al.*, 2020) and this richness of termites can be used to compare with earlier studies of different regions of India.So far, 73 species were listed from the Western Ghats (Paul *et al.*, 2018) whereas 68 species from the state Kerala in Southern India (Amina *et al.*,2016; Amina *et al.*, 2016). However, 27 and 37 species have been listed from the different localities of the north-western states Punjab and Haryana respectively (Anantharaju *et al.*, 2014; Poonia, 2019).

In this study, more than half (78%) of the termite species are recorded belonging to the Termitidae family, 39% in subfamily Macrotermitinae and 31% in genus *Odontotermes* (Fig. 2). These results support the records of previous studies that family

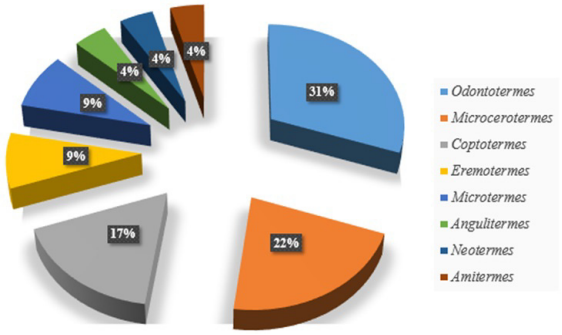

Fig. 2. Generic diversity of termitesat study sites.

Table 3. List of termite species recorded from six districts of Southern Haryana, India together with taxonomic positions respectively.

Species Name	Family	Sub-family	Ma	Re	Nu	Gu	Pa	Fa
Amitermes belli	Termitidae	Amitermitinae	-	+	+	+	+	-
E. paradoxalis	Termitidae	Amitermitinae	-	-	+	+	+	-
E. sp.	Termitidae	Amitermitinae	-	-	-	-	+	-
Micerocerotermes sp.1	Termitidae	Amitermitinae	-	-	+	-	-	-
M. beesoni	Termitidae	Amitermitinae	-	-	+	+	-	-
M. cameroni	Termitidae	Amitermitinae	-	-	-	-	+	-
M. sp.2	Termitidae	Amitermitinae	-	-	-	+	-	-
M. sp.3	Termitidae	Amitermitinae	-	-	-	-	-	+
Angulitermes sp.	Termitidae	Termitinae	-	-	+	-	-	-
Odontotermes assmuthi	Termitidae	Macrotermitinae	+	+	+	+	+	-
O. feae	Termitidae	Macrotermitinae	-	+	+	-	+	-
O. guptai	Termitidae	Macrotermitinae	+	+	+	+	+	-
O. gurdaspurensis	Termitidae	Macrotermitinae	+	-	+	+	-	-
O. obesus	Termitidae	Macrotermitinae	+	+	+	+	+	+
O. parvidens	Termitidae	Macrotermitinae	-	-	+	-	+	-
O. redemanni	Termitidae	Macrotermitinae	+	-	-	-	+	-
Microtermes obesi	Termitidae	Macrotermitinae	+	+	+	+	+	+
M. mycophagus	Termitidae	Macrotermitinae	+	+	+	+	+	+
Neotermes sp.	Kalotermitidae	-	-	-	+	-	-	-
Coptotermes sp.1	Rhinotermitidae	Coptotermitinae	-	-	-	+	-	-
C. sp.2	Rhinotermitidae	Coptotermitinae	+	+	-	-	-	-
C. heimi	Rhinotermitidae	Coptotermitinae	+	+	+	+	+	+
C. kishori	Rhinotermitidae	Coptotermitinae	+	+	+	-	+	+

*Ma-Mahendragarh, Re-Rewari, Nu-Nuh, Gu-Gurugram, Pa-Palwal, Fa-Faridabad

Termitidae is the predominant family comprised highest termite's diversity (Kakkar *et al.*, 2015; Aiman Hanis *et al.*, 2014; Ranjith and Kalleshwaraswamy, 2021).

Ten species (*O. assmuthi*, *O. guptai*, *O. gurdaspurensis*, *O. obesus*, *O. redemanni*, *Microtermes obesi*, *M. mycophagus*, *C. sp.2*, *C. heimi* and *C. kishori*) were recorded in Mahendragarh (Table 3), while ten

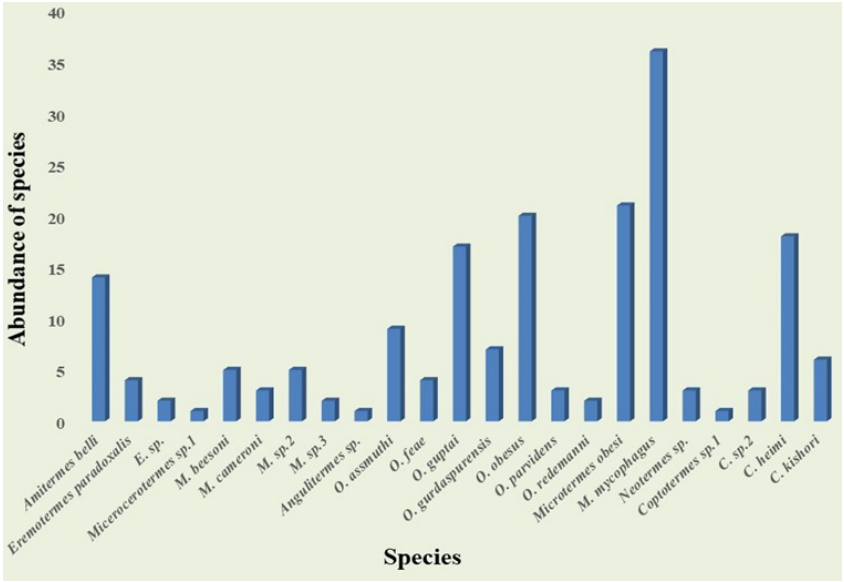

Fig. 3. Comparative abundance of termites at study sites.

species (*Amitermes belli, O. assmuthi, O. feae, O. guptai, O. obesus, M. mycophagus, M. obesi, C. sp.2, C. heimi* and *C. kishori*) were recorded in Rewari, sixteen from Nuh (*Amitermes belli, Eremotermes paradoxalis, Microcerotermes sp.1, M. beesoni, Angulitermes sp., O. assmuthi, O. feae, O. guptai, O. gurdaspurensis, O. obesus, O. parvidens, M. mycophagus, M. obesi, Neotermes sp., C. heimi* and *C. kishori*), twelve from Gurugram (*Amitermes belli, E. paradoxalis, M. beesoni, M. sp.2, O. assmuthi, O guptai, O. gurdaspurensis, O. obesus, M. mycophagus, M. obesi, C. sp.1,* and *C. heimi*), fourteen from Palwal (*Amitermes belli, E. paradoxalis, E. sp., M. cameroni, O. assmuthi, O. feae, O. guptai, O. obesus, O. parvidens, O. redmanni, M. mycophagus, M. obesi, C. heimi* and *C. kishori*) and six species (*M. sp.3, O. obesus, M. mycophagus, M. obesi, C. heimi* and *C. kishori*) were in Faridabad (Table 3). Among the species, only *M. mycophagus* (34) and *M. obesi* (21) were captured with the maximum in their number (Fig. 3).

Among the study sites, *O. obesus, M. mycophagus, M. obesi* and *C. heimi* were found to be common in all districts, whereas, *O. assmuthi* and *O. guptai* were found in all district except Faridabad while *M. sp.1, Angulitermes sp.* and *N. sp.* were recorded from Nuh district only, however species *C. sp.1* and *M. sp.2* noticed in Gurugram district, and *E. sp.* and *M. cameroni* from Palwal district only. This variation could be due to selected sites were surveyed. Nuh and Palwal districts had more termite species diversity as compared to others whereas Nuh district showed the highest species richness encountered 45 termite species followed by Mahendragarh 39, Gurugram 35, Palwal 32, Rewari 22, and Faridabad 14 (Table 4). Whereas, according to month wise species richness was found to be maximum in the months of May, June, July August and September (Fig. 5) (Ali *et al.*, 2013).

In termite species, the similarity was measured by Jaccard and Sorensen similarity indices, between the six selected study sites as shown in Table 5 and6. Results of the both indices emphasized that Mahendragarh and Rewari showed (0.67, 0.8) the highest similarity in termites groups, while mini-

Table 4. Occurrence and overall termite species richness in all selected study sites.

Species Name	Occurrence of termite species in different study sites					
	Ma	Re	Nu	Gu	Pa	Fa
Amitermes belli	0	2	6	4	2	0
Eremotermes paradoxalis	0	0	2	1	1	0
E. sp.	0	0	0	0	2	0
Micerocerotermes sp.1	0	0	1	0	0	0
M. beesoni	0	0	4	1	0	0
M. cameroni	0	0	0	0	3	0
M. sp.2	0	0	0	5	0	0
M. sp.3	0	0	0	0	0	2
Angulitermes sp.	0	0	1	0	0	0
Odontotermes assmuthi	3	1	2	2	1	0
O. feae	0	2	1	0	1	0
O. guptai	5	2	3	3	4	0
O. gurdaspurensis	4	0	2	1	0	0
O. obesus	5	3	4	3	4	1
O. parvidens	0	0	2	0	1	0
O. redemanni	1	0	0	0	1	0
Microtermes obesi	5	3	4	4	3	2
M. mycophagus	8	5	6	6	6	5
Neotermes sp.	0	0	3	0	0	0
Coptotermes sp.1	0	0	0	1	0	0
C. sp.2	2	1	0	0	0	0
C. heimi	4	2	3	4	2	3
C. kishori	2	1	1	0	1	1
Species Richness	39	22	45	35	32	14

*Ma-Mahendragarh, Re-Rewari, Nu-Nuh, Gu-Gurugram, Pa-Palwal, Fa-Faridabad

mum species' similarity was recorded in Faridabad with Gurugram district (0.29, 0.44). The maximum species similarity was noticed between Mahendragarh and Rewari districts might be ascribed to positive environmental condition. Habitats with greater structural similarity tended to present similar termite's groups (Shanbhag and Sundararaj, 2013). Microclimate, soil parameters, and vegetation are the main environmental cues that significantly change the termite communities (Basu *et al.*, 1996; Vidyashree *et al.*, 2018).

Diversity of species community in 6 districts of study area

Species diversity and richness varied across the study sites. Shannon's wiener index indicates that the values ranged from 1.40 to 2.59 in the study area. The index displays that Nuh had higher species diversity (2.59), followed by Palwal (2.38), Gurugram (2.30), Rewari (2.17), Mahendragarh (2.13), and lowest in Faridabad (1.40) sites (Table 7, Fig. 4). Similarly, Simpson's diversity index was ranged from 0.70 to 0.91. The dominance value was noted highest at 0.91 in Nuh, followed by Palwal (0.89), Gurugram (0.88), Rewari (0.87), Mahendragarh (0.86), while the lowest was at Faridabad (0.70). Species evenness value was used to know the distribution rate of termite fauna in the study areas. This evenness value was placed between 0.88-0.67 (Table 7). Evenness was highest (0.88) in Rewari followed by (0.84) in Mahendragarh, (0.83) in Nuh, (0.83) in Gurugram, (0.77) in Palwal, and least in Faridabad (0.67) (Table 7, Fig. 4).

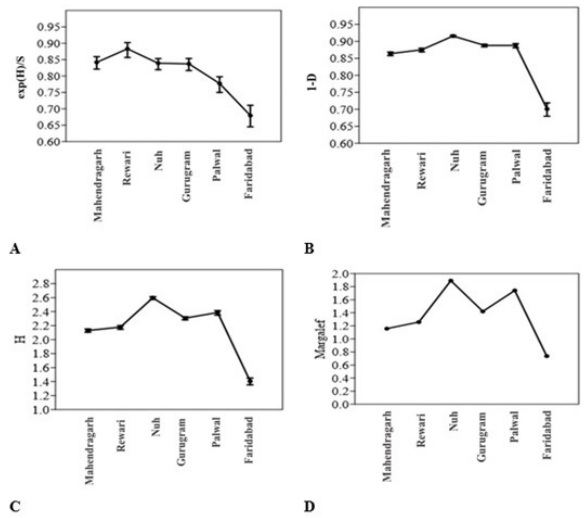

Fig. 4. Graph representing different indices a) Species evenness, b) Simpson index, c) Shannon index, d) *Margalef index*.

Margalef's diversity index was ranged between 0.73 to 1.89 in the study area (Table 7, Fig. 4). It is directly related to the species diversity scattered in the habitat. The highest value of Margalef's diversity index was observed in Nuh (1.89), followed by Palwal (1.74), Gurugram(1.42), Rewari (1.25), Mahendragarh (1.15), and lowest in Faridabad (0.73) and Menhinick's index was highest in Palwal (0.33) followed by Nuh (0.30), Rewari (0.27), Gurugram (0.25), Mahendragarh (0.21) and lowest in Faridabad (0.20). As we have calculated so many indices so there results are same for all indices like Simpson_1-D, Shannon_H and Margalef etc (Vidyashree *et al.*, 2018). This indicated that the highest species richness and diversity was noticed in the Nuh district than other districts.

Table 5. Jaccard's similarity index (Cj) of termite fauna between selected study areas.

Study area	Mahendergarh	Rewari	Nuh	Gurugram	Palwal
Rewari	0.67	-	-	-	-
Nuh	0.45	0.53	-	-	-
Gurugram	0.47	0.47	0.56	-	-
Palwal	0.5	0.6	0.58	0.45	-
Faridabad	0.45	0.45	0.30	0.29	0.33

Table 6. Sorensen s similarity index (â) of termite fauna between selected study areas.

Study area	Mahendergarh	Rewari	Nuh	Gurugram	Palwal
Rewari	0.8	-	-	-	-
Nuh	0.62	0.69	-	-	-
Gurugram	0.64	0.64	0.72	-	-
Palwal	0.67	0.75	0.73	0.62	-
Faridabad	0.63	0.63	0.46	0.44	0.5

Table 7. Species evenness and species diversity indices of termite fauna in different study sites.

Diversity index	Mahendragarh	Rewari	Nuh	Gurugram	Palwal	Faridabad
Taxa_S	10	10	16	12	14	6
Individuals	2382	1278	2773	2297	1747	887
Simpson_1-D	0.86	0.87	0.91	0.88	0.89	0.70
Shannon_H	2.13	2.17	2.59	2.30	2.38	1.40
Evenness_e^H/S	0.84	0.88	0.83	0.83	0.77	0.67
Menhinick	0.21	0.27	0.30	0.25	0.33	0.20
Margalef	1.15	1.25	1.89	1.42	1.74	0.73

As termites are seasonal insects, therefore their appearance rate is influenced by the favorable rainy season (Davies *et al.*,2014). Because this pado-fauna required optimum water level for its proper development (Ahmed and Pradhan, 2018) and most of the samples were collected from locality ranged 28°12247.76123 N & 77°5211.13723 E on the map. These results are closely verified with findings of Gathorne-Hardy *et al.*, (2001), Shanbhang and Sundararaj, (2011), Sattar *et al.*, (2013) and Ahmed *et al.*, (2018), who stated that the termite distribution rate is most probably influenced by temperature, rainfall and humidity. No individual termite species were sampled in the winter months because of the low temperature (December, January, February, and March) and high humidity. Additionally, the soil became moister during the winter season of the study. When the temperature increased, maximum numbers of termites were captured (Fig. 5). Termite species cannot colonize their colony in areas where the soil temperature is too cold and too hot (La Fage *et al.*, 1976; Smith and Rust, 1994). Hence, their colonies were found to be dependent on temperature. On average, a greater percentage of the wooden stakes were attacked in summer than winter (Sattar *et al.*, 2013). In the present studies, higher termites' diversity was observed in summer months (July, August, and September) when the atmospheric and ground temperature is favourable for termites' deeds in summer (Fig. 5).

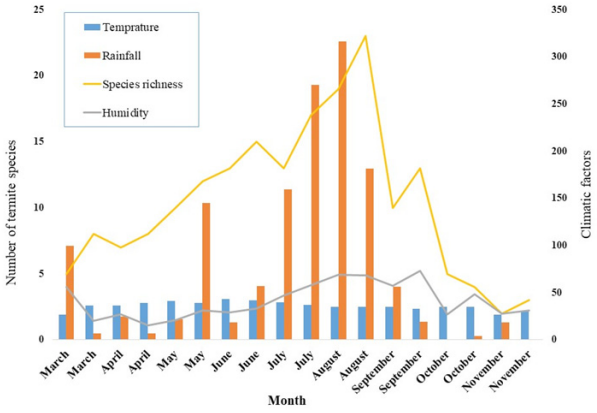

Fig. 5. Termite species richness in relation to climatic factors (temperature, humidity and rainfall) in study area during March, 2020 to November, 2021.

Conclusion

This present study represents the diversity indices done on termite species in the study sites (Southern Haryana). Twenty-three (23) termite species were morphologically identified from six districts of Southern Haryana. The Termitidae family found to be more diverse representing the highest species, followed by Rhinotermitidae and least in Kalotermitidae. The Macrotermitinae subfamily had the highest species in itself. Whereas, *M. mycophagus* and *M .obesi* were the most abundant species among them. The highest diversity was seen in Nuh and Palwal districts, whereas the highest species richness wasin Nuh (45) and Mahendragarh (39) districts followed by Gurugram 35, Palwal 32, Rewari 22, and Faridabad 14. Margalef's diversity index which is related to the distribution rate of species at habitat level was highest in Nuh and lowest in Faridabad. The lowest Margalef's index or sp. distribution rate in Faridabad due to direct or indirect disturbance of industries. During the study period, temperature was also noticed as a vital abiotic factor to the termites being more energetic. Therefore, termite activities were significantly correlated with maximum soil temperature, minimum temperature, minimum relative humidity, and rainfall.

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Conflict of interest

The authors have no conflicts of interest.

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