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Ants (Hymenoptera:Formicidae) Species Richness and Diversity in a Semi-Arid Region of India

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ABSTRACT

India is a mega-diversified country, where invertebrates, especially ant species, are not well known. This study reveals ant species diversity, richness, and relative abundance in three habitats of the Green Park area, Hisar, Haryana, a semi-arid region of India, during post-monsoon and winter seasons. Nine ant species were detected, representing seven genera and three subfamilies (Myrmicinae, Formicinae and Dolichoderinae). Myrmicinae was considered as the most dominant subfamily. Shannon-Weiner Diversity Index (H') in the human residential area, grass loan-2, grass loan-1, and horticultural field were 1.62, 1.17, 1.16, and 0.94, respectively, during post-monsoon season. It was 1.43, 1.36, and 1.21 throughout winter season. Simpson Diversity Index (1-D) values in grass loan 1 were found high in post-monsoon (0.72) and winter (2.50) season and low in horticultural field area (0.42) and (0.60) respectively. Margalef's species richness in human residence area (2.77) was slightly more than the horticultural field (2.02), grass loan 2 (1.89), and grass loan 1 (1.33), throughout the post monsoon season. However, the species richness in grass loan 1 (7.71) and grass loan 2 (7.71) was greater than human residence area (7.15) and horticultural field (7.15), in winter. So, this study shows that there are fewer species in the grass loan, and horticulture fields, which might be due to a scarcity of food or pesticide being used more frequently in this area for farming.

***Key words*:** Ant diversity, Shannon-Weiner diversity index, Margalef's index of richness, Pitfall, Species richness

The global diversity of insects is estimated to be roughly 5.5 million species [1]. Ants make a significant contribution to total animal biomass [2]. The global ant species exceeds 20,000 [3-4]. On the planet, there are over 13,837 ant species divided into seventeen subfamilies and 337 genera [5-6]. In comparison, 100 genera were reported with 828 valid ant species in India [7]. Among twelve mega-diverse countries, India received the sixth rank in ant species richness [8]. Ants are marked as strong environmental and social indicators. Ants considered as the eusocial insects of family Formicidae and order Hymenoptera [9]. Ants behave as significant predators, seed dispersers, mutualists, and some of them are infamous agriculture and forest pests [10-14]. There are five types of ants that do the most damage in the world, like *Anoplolepsis gracilipes*, *Linepithema humile*, *Pheidole megacephala* and *Wasmannia auropunctata* [15]. The global study, ant diversity decreased with increasing latitude [16]. Environmental factors like temperature, humidity, and habitat complexity were significant predictors of species richness [17]. Where elevation in temperature affects the species richness more dominantly [18], being a successful insect can face various anthropogenic activities [19].

Though India contributes to the global biodiversity hotspot with neighbuoring countries, ants are still the least studied group for their taxonomy in Haryana, India. There are very few studies on ant diversity in various habitats. It is important to register new records of known ant taxa.

The study aims to determine the ant species richness, abundance, and diversity in the different habitats of a defined area in Hisar, Haryana, India. These records are essential for developing knowledge about the discovered ant species and studying their morphological and functional traits.

MATERIALS AND METHODS

Study area

Hisar (29°09'N, 75°42'E) is a well-known semi-arid district close to Rajasthan, North India. The current study attempted to quantify ant diversity in three different ecological habitats: (1) grassland, (2) horticulture field, and (3) human residence areas, including dry land in Green Park area of Hisar (Fig 1). It lies between 29°8'33.90" N and 75°43'28.43" E. The study was conducted throughout two seasons: post-monsoon (September to November) and winter (December to February) in 2021. The soil type found in Hisar was loam. Grasslands and horticultural field prominently included grass. Grass loans 1

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and 2 surrounded plants belonging to various families, such as *Moraceae* and *Poaceae*. In contrast, the horticultural area was surrounded by the *Brassicaceae*, *Amaranthaceae*, *Solanaceae*, *Myrtaceae*, and *Amaryllidaceae* families. The average soil pH of the study site was slightly alkaline as the pH of grass loan 1, grass loan 2, and the horticulture field were 8.7, 8.8, and 8.9, respectively.

Fig 1 The study area; Green Park Area, Hisar, India

Sampling method

During post-monsoon (September 2021 to November 2021) and winter (December 2021 to February 2022), the ants were collected during the evening time using different methods. For the ant collection, three modes (pitfall, pooter, and handpicking) were employed.

Pitfall

Three pitfall traps were arranged on each transect line of 20 meters and installed from 7:00 pm to 7:00 pm for 24 hours. Pitfall looks like a white 500ml plastic container with an 11 cm diameter and a 6.5 cm height. During the post-monsoon and winter, a total of 52 pitfall traps were installed at sampling habitats. Throughout each season, nine pitfalls (Grass loan 1), nine pitfalls (Grass loan 2), and eight pitfalls (periphery of the horticulture field) were placed for ant collection. After installing the traps, 50 ml of ethylene glycol solution (1 part ethylene glycol, 3 parts distilled water, and a pinch of mild detergent) was poured into each container as a killing and preservative solution. A plane wire gauze plate covered the pitfall (area of pore = 0.84 cm^2 and area of wire gauze = 40 cm^2). 5 g of honey was used as attractant bait and placed at the centre of wire gauze to attract the ants.

Pooter

In human residence areas (indoors and outdoors), ants were captured easily using a pooter aspirator consisting of a transparent glass container (50 ml). The Pooter has a fixed lid on the container tip with two rubber tubes (mouth suction tube and insect suction tube) to capture the ants. Mouth suction tubes covered with muslin cloth to prevent ants from entering the mouth during aspiration. A small piece of ethyl acetate (a killing agent) dipped in Whatman's paper was placed inside the container to kill the captured ants.

Preservative method

After collection, the dead ants were first sorted, counted, washed, and then transferred to a 70% ethanol solution for prolonged preservation in the separated plastic vial (5 ml) Each species was counted to examine its species diversity and species richness.

Ant's identification

Ants were identified at Department of Biosciences, Gyan Path Himachal Pradesh University, Shimla, Himachal Pradesh, using a microscope (Leica M205C + DFC 295). Identified ants were arranged in their subfamily with the help of zoological keys given by Bharti *et al*. [20]. During the whole study, ant's pictures were captured with the help of an Android phone (Realme XT-RMX1921_11_C.01, 64MP camera).

Data analysis

Simpson's Diversity Index [21], Shannon and Weiner Diversity Index [22], and the *Margalef Index for Species richness or dominance* [22-23] were used for identification of ant's alpha diversity. In this research, the Shannon-Wiener Diversity Index (H') and Simpson Diversity Index (1-D) were calculated by standard statistical formula:

Margalef index for species richness or dominance

Total number of species present in different samples was examined using Margalef Index [23-24].

$$d = (S-1)/Log\ (N)$$

Where;
S = the no. of species in the sample,
n_i = the no. of individuals of species i in the sample,
$\sum n_i = N$ and N = total no. of individuals in the sample

Relative abundance

$$R_A = n_i / N$$

Where;
n_i = the number of individuals in the i^{th} species and
N = total number of individuals in the sample or sampling area [25].

Species equitability / evenness / Pielou's index of evenness

Species evenness was quantified with the help of Pielou's Evenness Index. How evenly the individuals were distributed among the different species. With increased species richness and evenness, diversity also increases [26-27].

$$J = H'/ln(S)$$

Where;
H' = Shannon-Weiner index value and
S = the no. of species in the sample

Shannon-Weiner diversity index

This included both species richness and evenness components [24].

$$H' = -\sum pi*ln(p_i)$$

Where;
p_i = the proportion of individual of species i in the sample, $p_i = n_i/N$
n_i = the number of individuals in the i^{th} species and
N = total number of individuals in the sample or sampling area

Simpson's diversity index

Simpson's (D) and Simpson diversity index (1-D) calculate the diversity that is the number of species present in an area, and the relative abundance of each species as 'D' defines the measure dominance. Hence, the higher the value of D, the lesser the diversity will be i.e., if D is zero, it means diversity will be infinity; if D is 1, then there is no diversity. In that case, diversity increases as the value of Simpson (1-D) increase [25].

$$Simpson\ Index\ (D) = \sum n_i(n_i^{-1})/N\ (N^{-1})$$
$$Simpson\ Diversity\ Index = 1-D$$

Where;
n_i = the number of individuals in the i^{th} species and
N = total number of individuals in the sample or sampling area

Surface temperature (Ts) and Surface relative humidity (R_H)

Digital thermo-hygrometer was used to measure the relative humidity of air on daily bases throughout the study period.

RESULTS AND DISCUSSION

In the Green Park Area of Hisar District, Haryana, 3,538 ants were found in three places: grassland, a horticultural field, and indoor and outdoor areas where people live. The weather data represents the variation in temperature, humidity and rainfall over time (Fig 2, Table 1). The ants were collected during the post-monsoon and winter seasons using pitfall and pooter aspirators, as shown in (Table 2-3). In our study, we reported nine species of ants belonging to seven genera and three subfamilies, namely Myrmicinae, Formicinae, and Dolichoderinae (Table 4). The subfamily Myrmicinae was the most dominant, with nine species and five genera (Table 5). Formicinae and Dolichoderinae were the second and third most productive subfamilies. The ant species and genera predominantly present in human residence area as compare to other habitats. But maximum subfamilies were observed in grass loan 2 as compare to other places (Fig 4). The distribution of ants was greatest in outdoor and indoor residence areas (outdoor and indoor), followed by horticultural fields and grassland areas. The ant species discovered at the study site had a range of 1.5 mm to 14 mm in size. *Camponotus compressus* was found to be the largest ant species (5 to 14 mm) Among the other species, *Messor himalayanus* (7 mm), *Pheidol indica* (5 mm), *Meranoplus bicolor* (3–3.5 mm), *Pheidole minor* (3 mm), *Monomorium pharaonis* (3 mm), and *Crematogaster sp*. (3 mm) are among the others. *Monomorium monimorium* (1.5) was the smallest ant in the study region (Fig 3, Table 4).

Table 1 Average temperature, humidity and rainfall during post-monsoon and winter season at the study area

Months	Average temperature (°C)	Temp. (Min.)	Temp. (Max.)	Relative humidity (%)	Hum. (Min.)	Hum. (Max.)	Average rain fall
Post-monsoon (September to November, 2021)							
September	29.10	24.00	33.80	80.07	59.00	99.00	4.75
October	26.27	20.00	30.70	63.74	31.20	91.00	0.10
November	20.73	14.70	25.70	56.25	36.00	79.40	0.05
Winter (December 2021 to February 2022)							
December	15.75	9.50	20.90	67.47	44.80	94.00	0.07
January	14.18	10.10	17.90	79.62	54.00	100.00	1.06
February	18.50	10.30	26.40	62.32	39.00	99.00	0.10

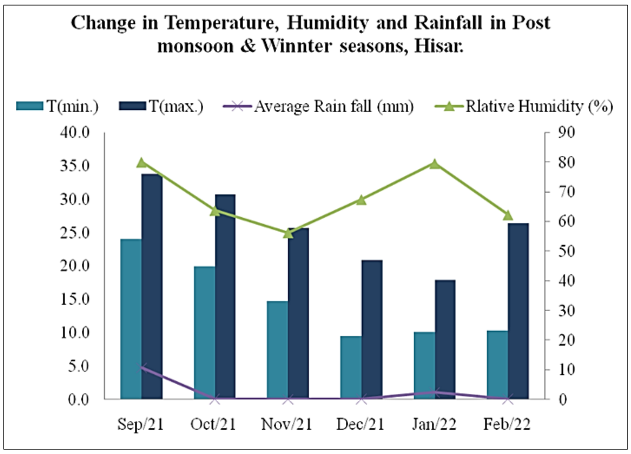

Fig 2 Minimum and maximum temperature, relative humidity and average rainfall during post-monsoon (Sept. to Nov. 2021) and winter season (Dec. to Feb. 2022)

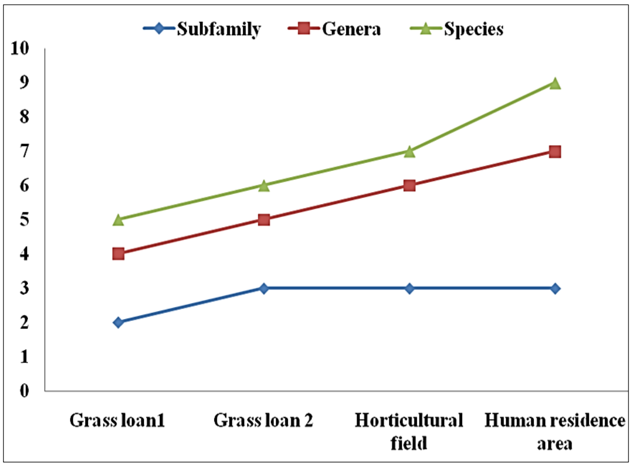

Fig 4 Habitat wise distribution of Ant's subfamilies, genera and species

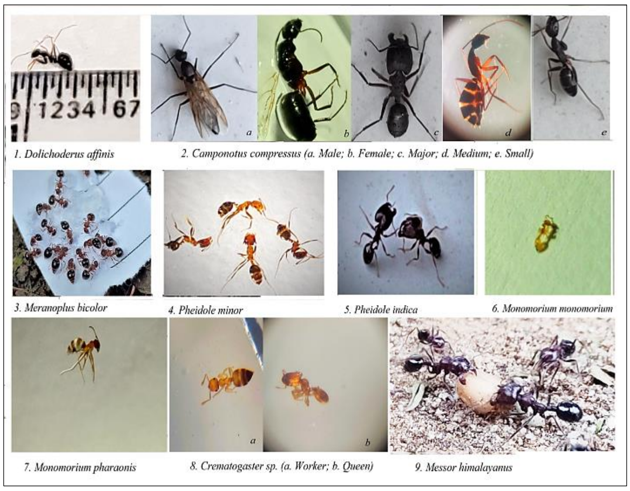

Fig 3 Ants collected from Green Park Area, Hisar

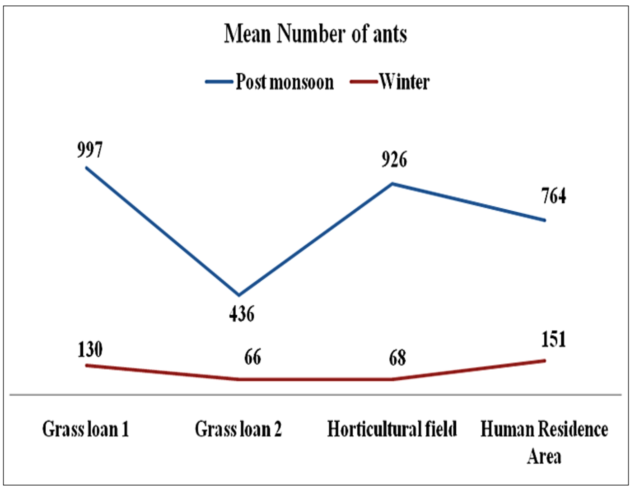

Fig 3 Ants collected from Green Park Area, Hisar

Table 2 Number of ant collected from different habitats. Grass loan 1, Grass Loan 2, Horticultural Field and Human residence area (Green Park Area, Hisar, Haryana, India)

Habitats	Sample	September to November, 2021									Total No. of ants
		a	b	c	d	e	f	g	h	i	
Grass loan 1	S_1	00	06	17	162	00	00	00	00	00	185
	S_2	00	12	30	150	00	00	00	00	00	192
	S_3	00	05	27	96	01	00	00	00	00	129
	S_4	00	18	08	07	00	10	00	00	00	43
	S_5	00	06	17	18	01	28	00	00	00	70
	S_6	00	25	47	08	00	12	00	00	00	92
	S_7	00	20	21	07	00	00	00	00	00	48
	S_8	00	02	148	00	00	00	00	00	00	150
	S_9	00	12	46	7	00	23	00	00	00	88
	Total = 9	00	106	361	455	02	73	00	00	00	997
Grass loan 2	S_{10}	00	00	10	01	00	01	00	00	00	12
	S_{11}	00	02	01	30	00	00	00	00	00	33
	S_{12}	00	01	01	04	00	00	00	00	00	06
	S_{13}	00	20	78	05	00	00	00	00	00	103
	S_{14}	11	01	01	00	00	00	00	00	00	13
	S_{15}	5	00	00	02	00	00	00	00	00	07
	S_{16}	00	13	44	115	00	07	00	00	00	179
	S_{17}	00	04	02	55	01	00	00	00	00	62
	S_{18}	00	07	08	05	00	01	00	00	00	21
	Total = 9	16	48	145	217	01	09	00	00	00	436
Horticultural field	S_{19}	00	02	10	59	00	00	00	00	00	71
	S_{20}	07	01	01	04	00	02	00	00	00	15
	S_{21}	00	04	42	92	02	11	00	00	00	151
	S_{22}	00	04	05	290	01	02	00	00	00	302
	S_{23}	02	01	00	00	00	00	00	00	00	03
	S_{24}	00	07	32	12	00	12	00	00	00	63
	S_{25}	00	07	02	211	04	03	00	00	00	227
	S_{26}	00	08	03	24	00	01	00	00	00	36
	S_{27}	00	00	00	00	00	00	00	58	00	58
	Total= 9	09	34	95	692	07	31	00	58	00	926
Human residence area	S_{28}	12	00	00	262	00	00	00	00	00	274
	S_{29}	00	00	00	100	00	00	00	00	00	100
	S_{30}	20	08	00	00	00	00	00	00	00	28
	S_{31}	00	00	00	00	00	00	62	00	00	62
	S_{32}	00	14	00	00	17	00	00	00	00	31
	S_{33}	00	00	00	00	00	00	00	128	00	128
	S_{34}	04	04	00	00	00	00	00	00	65	88
	S_{35}	00	53	00	00	00	00	00	00	00	53
	Total = 8	36	79	06	362	17	09	62	128	65	764
		December 2021 to February 2022									
Grass loan 1	S_1	00	00	00	09	00	00	03	00	00	12
	S_2	00	00	00	03	00	00	01	00	00	04
	S_3	01	00	00	02	00	13	00	00	00	16
	S_4	00	00	00	01	00	00	05	00	00	06
	S_5	00	00	00	03	00	02	01	00	00	06
	S_6	00	02	00	00	00	00	00	00	00	02
	S_7	02	05	00	29	00	00	00	00	00	36
	S_8	00	01	00	02	01	01	00	00	00	05
	S_9	00	00	00	01	00	01	01	00	00	03
	Total = 9	03	08	00	50	01	17	11	00	00	90
Grass loan 2	S_{10}	00	00	00	00	00	01	00	00	00	01
	S_{11}	00	02	00	00	00	13	00	00	00	15
	S_{12}	00	00	00	04	00	00	00	00	00	05
	S_{13}	00	02	01	00	00	00	02	00	00	05
	S_{14}	01	00	00	08	01	00	00	00	00	11
	S_{15}	00	02	00	02	00	00	00	00	00	04
	S_{16}	03	01	00	04	00	00	00	00	00	09
	S_{17}	00	02	00	08	00	00	00	00	00	10
	S_{18}	00	03	00	05	01	00	00	00	00	08
	Total = 9	04	12	01	31	02	14	02	00	00	66

Horticultural field	S_{19}	00	00	00	03	00	00	00	00	00	03
	S_{20}	00	00	00	03	00	00	00	00	00	03
	S_{21}	00	00	00	00	00	00	00	00	00	00
	S_{22}	00	02	00	01	00	00	02	00	00	05
	S_{23}	03	00	00	00	00	00	00	00	00	03
	S_{24}	00	02	00	01	00	00	05	00	00	08
	S_{25}	00	00	00	00	00	00	00	00	00	00
	S_{26}	00	06	00	02	01	02	01	00	00	12
	S_{27}	02	00	00	31	00	00	01	00	00	34
	Total = 9	05	10	00	41	01	02	09	00	00	68
Human residence areas	S_{28}	00	01	00	15	03	00	09	00	00	28
	S_{29}	03	00	00	00	00	00	00	00	12	15
	S_{30}	00	05	00	17	02	00	05	00	00	29
	S_{31}	01	00	00	11	01	00	00	00	04	17
	S_{32}	00	02	00	00	00	00	03	00	00	05
	S_{33}	04	00	00	10	03	00	00	00	00	17
	S_{34}	00	00	00	00	00	00	07	00	07	14
	S_{35}	00	03	00	21	02	00	00	00	00	26
	Total = 8	08	11	00	74	11	00	24	00	23	151

(a) *Dolichoderus affinis*, (b) *Camponotus compressus*, (c) *Meranoplus bicolor*, (d) *Pheidole minor*, (e) *Pheidole indica*, (f) *Monomorium monomorium*, (g) *Monomorium pharaonis*, (h) *Crematogaster*, (i) *Messor himalayanus*

Table 3 Number of ant species collected from three habitats with the help of pitfall and pooter methods, during post monsoon (September to November, 2021) and winter (December to February, 2022) season

Ant species / habitats	Grass loan 1	Grass loan 2	Horticultural field	Human residence area	Total number of ants
Post monsoon (September to November, 2021)					
Dolichoderus affinis	00	16	09	36	61
Camponotus compressus	106	48	34	79	267
Meranoplus bicolor	361	145	95	06	607
Pheidole minor	455	217	692	362	1726
Pheidole indica	02	01	07	17	27
Monomorium monomorium	73	09	31	09	122
Monomorium pharaonis	00	00	00	62	62
Crematogaster	00	00	58	128	186
Messor himalayanus	00	00	00	65	65
Total ants species = 09 Total No. of ants = 3,123	997	436	926	764	3,123
Winter (December to February, 2022)					
Dolichoderus affinis	03	04	05	08	20
Camponotus compressus	08	12	10	11	41
Meranoplus bicolor	00	01	00	00	01
Pheidole minor	73	31	41	74	219
Pheidole indica	01	02	01	11	15
Monomorium monomorium	17	14	2	00	33
Monomorium pharaonis	11	02	09	24	46
Crematogaster	00	00	00	00	00
Messor himalayanus	17	00	00	23	40
Total ants species = 09 Total No. of ants =415	130	66	68	151	415

Table 4 Subfamily wise checklist of ant genera and identified species

Subfamily	Name	Ant size (mm)		References
Dolichoderinae	*Dolichoderus affinis*	3 mm		Emery, 1889
Formicinae	*Camponotus compressus*	14 mm (Queen) 8.5 mm (Male) 12 mm (Major)	7 mm (Medium) 5 mm (Minor)	Fabricius, 1787
Myrmicinae	*Meranoplus bicolor*	3.0-3.5 mm		Guerin-meneville, 1844
	Pheidole minor	3 mm		Jerdon, 1851
	Pheidole indica	5 mm		Mayr, 1879
	Monomorium monomorium	1.5 mm		Bolton, 1987
	Monomorium pharaonis	3 mm		Linnaeus, 1758
	Crematogaster sp.	3 mm (Queen), 2 mm (Worker)		Forel, 1902
	Messor himalayanus	7.5 mm		Forel, 1902

Table 5 List of ants collected in Green Park area, Hisar, Haryana, India (2021-2022)

Subfamily	Genera	Species
Dolichoderinae	*Dolichoderus*	1
Formicinae	*Camponotus*	1
Myrmicinae	*Meranoplus*	1
	Pheidole spp.	2
	Monomorium	2
	Crematogaster	1
	Messor	1
Total	07	09

According to favourable conditions such as food, temperature, humidity, and so on, ant species distribute themselves in various habitats, as we examine their distribution in grass loans, horticulture fields, and household areas. The statistics in (Table 6) display the general area selected by ant species for their residence, where all ant species have adapted to exist in human residence areas (indoors and outdoors) During the post-monsoon season, the average number of ants in grass loan 1 was 997, followed by a horticulture field (926), a human residence (764), and grass loan 2 (436). During the winter season, the human residential area has 151 ants, followed by grass loan 1 (120), horticulture field (68), and grass loan 2 (66), as given in (Fig 5).

Table 6 Distribution of ant species in different habitats of Hisar district

Ant species	Habitats				
	Grass loan-1	Grass loan-2	Horticultural field	Human residence area (Indoor)	Human residence area (Outdoor)
Dolichoderus affinis	+	+	+	+	+
Camponotus compressus	+	+	+	+	+
Meranoplus bicolor	+	+	+	-	+
Pheidole minor	+	+	+	+	-
Pheidole indica	+	-	+	+	-
Monomorium monomorium	+	-	-	-	+
Monomorium pharaonis	-	-	-	+	-
Crematogaster sp.	+	+	-	+	+
Messor himalayanus	-	-	-	-	+

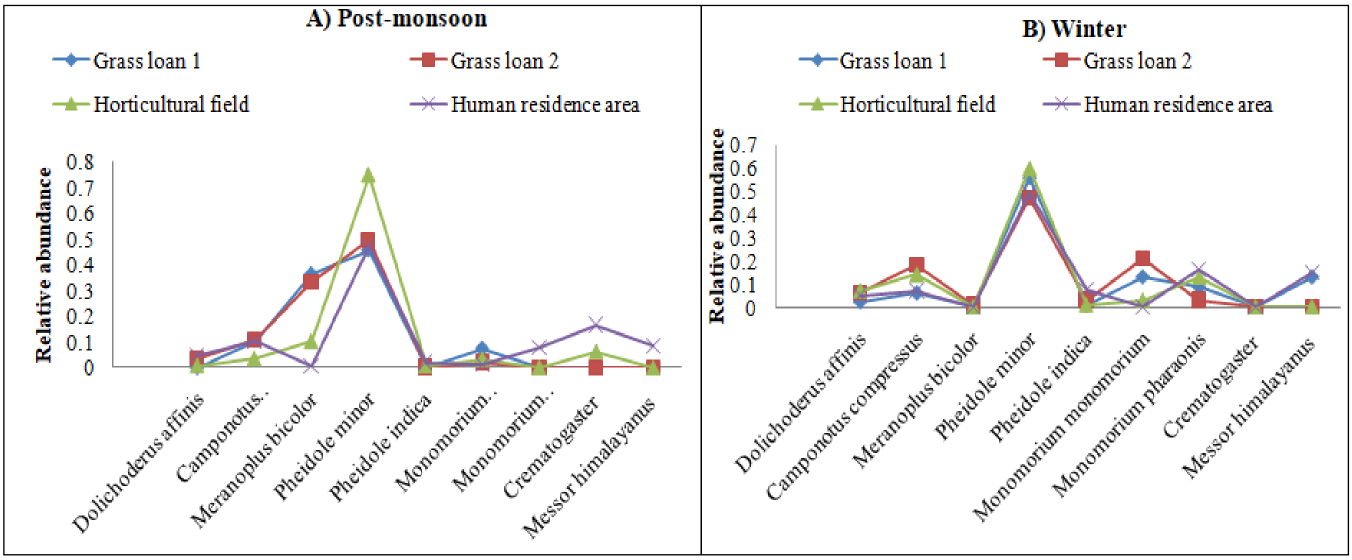

Fig 6 Relative abundance (RA) = pi = (ni/N), of ants species at study site, during post-monsoon (A) and winter season (B)

Pheidole minor shows maximum relative abundance in the post monsoon season as well as in winter as compared to the other ant species. The study expresses that during the post-monsoon season, *Pheidole minor* shows maximum relative abundance in horticultural fields (0.74), grass loan 2 (0.49), human residence area (0.47), and grass loan 1 (0.45) (Fig 6a), and in winter season it was maximum in horticultural fields (0.60), grass loan 1 (0.56), human residence area (0.49), and grass loan 2 (0.47) (Fig 6b). The post-monsoon mean relative abundance of *Pheidole minor* ant species was 55%, followed by *Meranoplus bicolor* (20%) and *Camponotus compressus* (9%) In the winter season (Fig 7a), it was maximum, i.e., 54% in the case of *Pheidole minor* followed by *Camponotus compressus* (12%) (Fig 7b). *Pheidol minor* and *Merannoplus bicolor* ant species were considered most abundant during the post-monsoon season, but all other species seem to be active during the winter season (Fig 7c).

The diversity measured by the Shannon-Weiner Diversity Index (H') in the human residence area, grass loan-2, grass loan-1, and horticultural field was 1.62, 1.17, 1.16, and 0.94, respectively, during the post-monsoon season. On the other hand, throughout the winter season, it was 1.43, 1.36, and 1.21 in the human residence area, grass loan-2, grass loan-1, and horticultural field, respectively, which was slightly less than in the post-monsoon season (Table 7, Fig 8c). The diversity calculated by the Simpson Diversity Index (1-D) for ant species during the post-monsoon as grass loan 1 with maximum diversity (0.72) followed by grass loan 1 (0.64), grass loan 2 (0.63) and it was the minimum (0.42) in the horticultural field area (Table 7, Fig 8d). Still, during winter, it was maximum in gross loan 1 (2.50), followed by human residence (1.13), grass loan 2 (0.71), and minimum in the horticultural field (0.60). Margalef's species richness (Table 7, Fig 8b) during the post-monsoon season was considered 2.77 in the human residence area, greater than the horticultural field (2.02), GL 2 (1.89), and GL 1 (1.33). It was the same in GL 1 and 2 (7.71) in the winter season, which was greater than the human residence area and horticultural field, i.e., 7.15 in each. Post-monsoon season represents maximum species evenness by Pielou in all study areas as compare to winter season, except the grass loan 1 (Fig 8a).

Table 7 Ant species richness, diversity, evenness by using Margalef's species richness method, (d) = (S-1)/Log(N); Shannon-Weiner Diversity Index (H') = $-\sum p_i \ln(p_i)$; Equaitablity or Pielou's evenness J = H'/ln(S)

September to November, 2021				
Ants	n_i* (Grass loan 1)	n_i* (Grass loan 2)	n_i* (Horticultural field)	n_i* (Human residence area)
Dolichoderus affinis	00	16	09	36
Camponotus compressus	106	48	34	79
Meranoplus bicolor	361	145	95	06
Pheidole minor	455	217	692	362
Pheidole indica	02	01	07	17
Monomorium monomorium	73	09	31	09
Monomorium pharaonis	00	00	00	62
Crematogaster	00	00	58	128
Messor himalayanus	00	00	00	65
No. of individual in sample ($\sum n_i = N$)	997	436	926	764
Total no. of species (S)	05	06	07	09
(S-1)	04	05	06	08
Log(N)	2.99	2.63	2.96	2.88
Species richness (Margalef) d =(S-1)/Log(N)	1.33	1.89	2.027	2.77
Species Equitability / Evenness / Pielou's evenness (J) = H'/ln(S)	0.725	0.653	0.483	0.642
Shannon-Weiner Diversity Index (H') = $-\sum pi*ln(p_i)$	1.168	1.171	0.941	1.620
Simpson's Index (D) = $\sum n_i(n_i-1)/N\ (N^{-1})$	0.36	0.37	0.58	0.28
Simpson's Diversity Index (1-D)	0.64	0.63	0.42	0.72
December to February, 2022				
Ants (Scientific Name)	n_i* (Grass loan 1)	n_i* (Grass loan 2)	n_i* (Horticultural field)	n_i* (Human residence area)
Dolichoderus affinis	3	4	5	8
Camponotus compressus	8	12	10	11
Meranoplus bicolor	0	1	0	0
Pheidole minor	73	31	41	74
Pheidole indica	1	2	1	11
Monomorium monomorium	17	14	2	0
Monomorium pharaonis	11	2	9	24
Crematogaster	0	0	0	0
Messor himalayanus	17	0	0	23
No. of individual in sample ($\sum n_i = N$)	130	66	68	151
Total no. of species (S)	7	7	6	6
(S-1)	6	6	5	5
Log(N)	0.77	0.77	0.69	0.69
Species richness (Margalef) d = (S-1)/Log(N)	7.71	7.71	7.1	7.15
Equitability/Evenness/Pielou's evenness (J) = H'/ln(S)	0.69	0.73	0.67	0.81
Shannon-Weiner Diversity Index (H') = $-\sum pi*\ln(p_i)$	1.36	1.43	1.21	1.46
Simpson's Index (D) = $\sum n_i(n_i-1)/N$ (N-1)	3.5	0.29	0.4	2.13
Simpson's Diversity Index (1-D)	2.5	0.71	0.6	1.13

Where;
n_i* = Number of individuals in a single sample.
S = the no. of species in the sample,
n_i = the no. of individuals of species i in the sample,
$\sum n_i = N$ and N = total no. of individuals in the sample and
p_i = the proportion of individual of species i in the sample, $p_i = n_i/N$

In comparison, 100 genera with 828 valid ant species were reported in India [26]. Ants are marked as strong environmental and social indicators and are collectively classified into a single family, the Formicidae, in the order Hymenoptera [27]. A record of 489 ant species was documented by Ryder *et al.* [28] in the Amazon, Ecuador. Ants in Acadia National Park (USA) were researched by Ouellette *et al.* [29], and their investigation exposed the data of two new species, including 42 ant species. Karmaly and Sumesh [30] found a *Cerapachys* ant species in the Palakkad district of Kerala, India. Guenard *et al.* [31] conducted extensive documentation on the ant population and richness in Nepal. Bharti [32] described two new species, *Myrmica adrijae* of the smythiesii species group and *Myrmica pseudorugosa* of the rugosa species group, from the Himalaya's north-western and north-eastern regions, respectively. In another study, Bhati *et al.* [33] updated a new checklist of 144 ant species belonging to 45 genera and five subfamilies (dominant subfamily-Myrmicinae) from the Himalaya. Bharti and Wachkoo [34] described two new species, *Cerapachys browni* and *Cerapchys costatus* species, from India. They found a new carpenter ant species (*Camponotus parabarbatus*) from the Shivalik hills of India. Bharti and Rilta [35] investigated *Stigmatomma xui* ant species collected from the north-eastern Himalaya. A list of 13 ant species from Indira Gandhi Garden, Bhiwandi, Maharashtra (India) was given by Momin *et al.* [36]. However, the checklist of Indian ants with their specific distribution in Indian states is described by Bharti [37]. A record of a total of 181 ant species in the Shivalik Mountains of the Himalayas and 99 species from the central western Ghat, Karnataka [38]. Yashavantkaumar [39] and his team exposed the ant diversity on the university campus of Karnataka, India, in 2016. Sonune and Havan [40] further investigated the variety and distribution of ants in different habitats such as agriculture, grassland, forest and human residences of Gautala Autramghat Sanctuary, District Aurangabad, Maharashtra, India. They found 17 ant species belonging to 13 genera under six subfamilies such as Aenictinae, Dolichoderinae, Formicinae, Myrmicinae, Ponerinae, and Pseudomyrmicinae. According to their findings, grassland was found to be a dominant habitat type as compared to others. Mahalakshmi and Channaveerappa [41] delved into ant diversity in the campus of Maharani's Science College, Mysuru City, Karnataka. A total of 20 species belonging to 12 genera and four subfamilies of ants existed on a college campus. Out of them all, the most diverse subfamily was Myrmicinae. Azhagu *et al.* [42] studied a total of ten ant species belonging to nine genera and four subfamilies (Formicinae, Myrimicinae, Pseudomyrimicinae, and Colichoderniae). The subfamily Formicidae recorded the maximum diversity of ants, with two ant species under the genera Camponotus and Formicidae. Yong *et al.* [16] collected four native ant genera from Singapore Island.

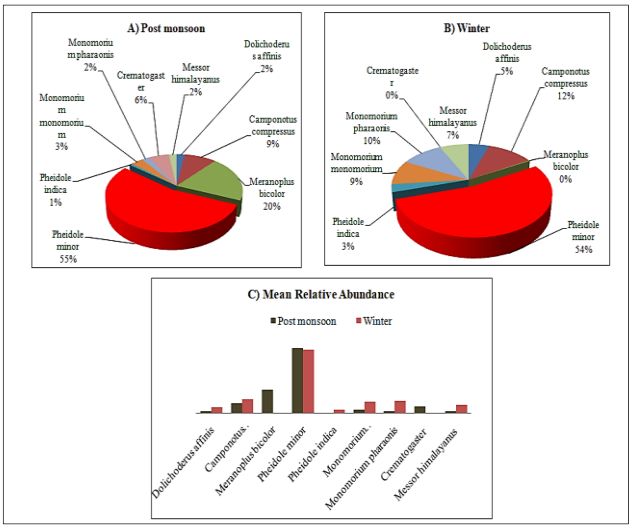

Fig 7 Comparative mean relative abundance of ants in post-monsoon (A) and Winter (B) seasons and species wise mean relative abundance (%) (C)

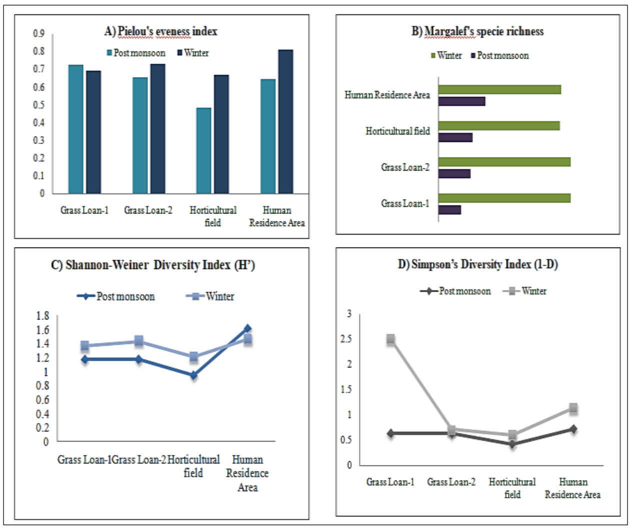

Fig 8 Species diversity indices. A) Pielou's eveness or Species equitability, B) Margalef's specie richness, C) Shannon-Weiner Diversity Index (H'), D) Simpson's index of diversity (1-D) of ant in different habitats

Chate and Chavan [43] found that in a Pri-Urban area with dominant ant species, sixteen ant species belonging to 12 genera and four subfamilies were reported. A list of 22 ant species from Parganas, West Bengal, India was published by Purkait [19]. Wachkoo *et al.* [34] added a new genus, *Leptogenys*, to the checklist of Indian ants. The subfamily Myrmicinae contributed 45.46 percent, according to their findings. Neupane and Subedi [44] catalogued the ants of the Pokhri area of Shivapuri Nagarjun National Park, Nepal. Gayathri and Roopavathy [45] explained a total of six subfamilies, including the most dominant subfamily, Myrimicinae, in two different areas of Thrissur district, Kerala, India. They found more diversity in agriculture as compared to industrial areas. The exploration of Western Ghat, India, by the author recorded 173 species. Of those, eight species were newly recorded [46]. An inquiry by Karthick *et al.* [47] revealed 12 ant species from that area. Abdar [48] investigated the species diversity of ants in the majority of the subfamily, Formicidae, in the Sangli district of Maharashtra (India). They explained that a total of twelve species belong to nine genera and five subfamilies. Adhikari *et al.* [49] discovered 18 ant species belonging to 12 genera and four subfamilies. In 2021, for the first time, five different species of *Camponaotus* genera were found. In new data of Brazillian Amazons, 46 ant species belonging to 23 genera, where the Pheidol genera are found prevalently, and 31 new ant species belonging to 5 subfamilies were named in a checklist of Indian ant species that was studied on a college campus in West Bengal [50-51]. Begum *et al.* [52] revised the ant species richness in semi-arid regions; they found 40 species belonging to 25 genera and six subfamilies. The district of Coimbatore in Tamil Nadu had a favourable climate for the ants of the dominant Myrmicinae subfamily. Further, Subedi *et al.* [53] identified 70 ant species belonging to 6 subfamilies in the forest area of Nepal. Begum *et al.* [54] collected a total of 11,038 worker ants belonging to 39 species, 22 genera and six subfamilies in the agricultural, vegetative, dry land, and human activity areas of Kalaburagi district, Karnataka, India. Baidya and Bagchi [55] reported data about 68 ant species, 35 genera, and nine subfamilies in Goa, India. The overall review of previous studies focused on the most abundant Myrmicinae subfamily.

All these findings are corroborated by the present research, and we reported that the most dominant subfamily is Myrmicinae. The species *Pheidole minor* was documented from all the habitats of the survey site. In grassland and horticultural fields, *Meranoplus bicolor* was the second most prevalent species, but the *Crematogaster* genus was higher in the human residence area. In a nutshell, the values of all the diversity indexes represent the maximum ant diversity measured in human residence areas compared to other habitats during both seasons. In the case of ant species richness, it was more common in grassland during winter, but more common in areas where people lived after the rain.

CONCLUSION

Diversity and species richness estimators like Simpson's Diversity Index (1-D), Shannon-Weiner Diversity Index (H), and Margalef's Index of species Richness clearly represent the diversity of ants in this area. All these diversity indices represent the maximum ant diversity found in human residence areas as compared to other habitats during both seasons. The subfamily Myrimicinae was the most dominant of all subfamilies. Pheidol minor was the most dominant species found on the study site, i.e., the overall relative abundance of this species was higher as compared to other species. Whereas, it was also concluded that ant species diversity, richness, and relative abundance vary in three habitats and two seasons. In the case of species richness, during the winter season, it was dominant in grassland areas and during the post-monsoon season, it was higher in human residence areas. The study reported that during the post-monsoon season, grass loan number 1 was enriched by ants, but during the winter season, human residences (indoor and outdoor) areas were the most favourable habitats for the ant residence. The present study may provide valuable data about ant species availability, which will be helpful for agricultural myrmecology and entomology in Haryana, India.

Conflict of interest

The authors declare that there is no conflict of interest.

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