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Seasonality of carabid beetles and effect of weather parameters on their diversity collected at Western Ghats of Karnataka using light and pitfall traps

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Abstract
The study conducted to understand the seasonality of carabids and impact of weather factors on the diversity of carabids in Mudigere, Chikkamagalur district, Karnataka, in three ecosystems *viz*., cardamom, coffee and mixed cropping ecosystems resulted in various outcomes. One UV light trap and six pitfall traps were set up at weekly intervals in all the three ecosystems. The collected carabids were processed and identified possibly up to subfamily level. A total of 1,782 individuals and 45 species were collected comprising 14 subfamilies, 37 genera and 20 tribes from all the three ecosystems, representing 677, 527 and 578 individuals and 45, 42 and 43 species in coffee, cardamom and mixed cropping ecosystem, respectively. When seasonality of the beetles was observed using Woldas's seasonality classification, most of the carabid species collected had highly seasonal activity and very few were more or less observed in all the seasons. Further, significant correlation between abundance and different weather parameters did not exist for pooled data of light and pitfall traps in any of the three ecosystems whereas species richness was significantly correlated with maximum and minimum temperature in coffee ecosystem. Similarly, with respect to light and pitfall trap collections all weather parameters had significant influence on adult activity in at least one of the three ecosystems whereas for species richness minimum temperature, RH1 and RH2 were significantly correlated.

Keywords: Seasonality, Shannon Weiner index, Wolda, carabids, light and pitfall traps

Introduction
Ground beetles or carabid beetles are one of the major groups of soil fauna which forms a distinct taxon within the suborder Adephaga and family Carabidae consists of about 1500 genera and 40,000 species worldwide (Zhang, 2011) [17]. Most members are predacious and are morphologically defined by the presence of six abdominal ventrites and pygidial defence glands in the adults (Lawrence and Britton, 1991) [8]. They have prominent mandibles and palps, long slender legs, striate elytra and sets of punctures with tactile setae. The adults are dark coloured, shiny or matte. Some have bright or metallic colours and some are pubescent (Lawrence and Britton, 1991: Crowson, 1981) [8, 4]. Carabids live in nearly every available habitat although some species are associated with ecosystems like meadows, woodlands or crop fields and are important indicators of ecosystem. They are mostly opportunistic feeders that consume a variety of foods. Most species locate food by random search, although some day-active (diurnal) species hunt by sight. A few species have also been observed to detect chemical cues from springtails, molluscs and aphids (Lovei and Sunderland, 1996) [10]. In recent ecological studies, carabids have received increasing attention in other parts of the world because of their importance in predatory processes (Luff, 1987) [11] and due to their major impact as bio-indicator of habitat degradation (Dushenkov, 1984; Luff *et al*., 1989; Thakare *et al*., 2013) [5, 12, 15]. Measures of carabid's ecological diversity, similarity, their variations over time and space, their interactions with the physical and biotic environment and extent of specialization in food intake provide an explanation for their diversity. Carabids depend on several biotic and abiotic factors. These include temperature or humidity, food conditions, presence and distribution of competitors, life history and season.
Keeping these facts in view, a comprehensive study was conducted to understand the seasonality and effect of weather parameters on diversity of carabids in different ecosystems of Mudigere using two types of traps.

Materials and Methods

The study was conducted at Mudigere in three ecosystems *i.e.*, the sampling sites included Cardamom plantation at Zonal Agricultural and Horticultural Research Station (ZAHRS), Mudigere; Coffee plantation (farmer's field), and mixed cropping ecosystem at College of Horticulture, Mudigere at an altitude of 982 m above Mean Sea Level. All the three locations in Mudigere taluk come under the Agroclimatic region-VI and Zone-9 (Hill zone) of Karnataka and these regions are characterised by heavy rainfall along the Western Ghats, in South India, which is recognised as eighth biodiversity hotspot globally. One light trap and six pitfall traps were setup at each site from August 2018 to March 2019 at weekly intervals from 6.00 p.m. in the evening to 6.00 a.m. in the next day morning (Plate 1). Containers were provided with saline and soap solution as the killing agent at the bottom of the light trap and for pit fall traps to collect the insects. The light trap was made up of a funnel fitted with two plastic panes crossing each other, two UV lights were fitted in the middle of the panes and a container was placed below the mouth of the funnel to collect the insects that was half-filled with saline water and soap solution as killing agent (Plate 1). The pitfall trap was a smooth surfaced plastic container with 6 to 8 cm diameter and 20 to 30 cm depth which were placed inside the soil with its rim equal to ground surface and protected from rain by placing a shelter over the plastic container. These containers were also provided with saline and soap solution as the killing agent. The light attracted and pit fall trapped insects were collected from these containers, washed thoroughly, sorted into morpho types and were given a species code. Finally, the unidentified samples were submitted to experts for their identification.

Plate 1: Pitfall and light trap for collection of carabid beetles

Measures of diversity

The abundance data with respect to species were tabulated and analyzed suitably to elicit information on patterns of activity of carabids in the three ecosystems of Mudigere. Species richness, Shannon-Weiner Index and Simpson's reciprocal index were estimated. These diversity indices were calculated for all data collected across time to ascertain the temporal changes in the diversity of carabids across the three sampling locations. Inter-relationships among the various measures of diversity were also worked out using Pearson's product moment correlation. The diversity indices used for analyses are listed below.

1. Shannon Weiner index

$$H' = -\Sigma p_i \ln p_i$$

Where,

p_i = the proportion of individuals of species i.

2. Simpson's reciprocal index

$$J=1/D$$

Where,

D= Simpson index value

Seasonality

Wolda (1988) [16] indicated that there could be three major kinds of seasonality patterns among insects with respect to seasonality patterns of insects attracted to light traps, which could be further divided into three sub groups, providing as many as nine types of seasonality patterns that are expected to be found among insects. The nine seasonality patterns with three major seasonalities enlisted by Wolda (1988) [16] are,

1. **Phenomenon does not occur throughout the year, but there is**

1A. One clear seasonal maximum
1B. More than one seasonal maximum
1C. A broad seasonal maximum

2. **Phenomenon occurs throughout the year and there is**

2A. One sharp/ clear seasonal maximum
2B. More than one clear seasonal maximum
2C. A broad seasonal maximum

3. **Phenomenon is a seasonal**

3A. Occurs constantly around the year
3B. Unpredictable irregular variation in occurrence, unrelated to seasons
3C. Clear maxima, at predictable sub-annual or supra-annual intervals, unrelated to seasons.

Therefore, an attempt was made to observe the above patterns of seasonality among the carabids caught during the study period. For this purpose, the abundance plots across time for each of the species were developed and using these graphical representations the seasonality classes were identified for all species encountered during study.

Weather parameters and adult activity

The activity patterns of carabids both by number of individuals and by number of species were correlated with various weather parameters. Total rainfall, mean maximum temperature, mean minimum temperature, mean maximum humidity (RH1) and mean minimum humidity (RH2) up to one week of trapping were used for working out the correlation coefficients. All correlations were run using SPSS software and MS excel was used to generate the scatter plots.

Results and Discussion

Seasonality patterns of carabid beetles as per the classification of Wolda, 1988 [16]

The abundances of all the morpho-species collected at coffee, cardamom and mixed cropping ecosystems in Mudigere during 2018-19 using light traps and pitfall traps were plotted against the sampling dates. Assuming that the natural field activity is reflected in the light and pitfall trap catches of the species, these plotted graphs were used to characterize the seasonality of each carabid species encountered in each ecosystem. The activity graphs of each of the carabid species were matched with the hypothetical scatter plots of all the nine classes of the phenological (or seasonality) patterns described by Wolda (1988) [16] and accordingly, each species was put under one of the nine categories of the seasonality patterns (Table 1). The number of individuals and species collected during the sampling duration showed a trend towards seasonality, with major numbers during monsoon and post monsoon season and smaller numbers during winter and summer (According to Indian Meteorological Department classification). Certain species exhibited only one type of seasonality pattern irrespective of ecosystems and type of sampling. However, certain other species trapped during the study varied in their seasonality with respect to ecosystems. Few species were also collected in all seasons *i.e*., throughout the year. The findings of the seasonality patterns of 45, 42 and 43 species of carabid beetles collected in coffee, cardamom and mixed cropping ecosystems, respectively at Mudigere during 2018-19 are as follows.

Table 1: Classification of collected carabid species into different seasonality classes as per Wolda (1988) [16]

Sl. no.	Species code	Genera	Seasonality class		
			Coffee	Cardamom	Mixed
1	Sp 1	*Dioryche* sp1	2B	2A	2A
2	Sp 2	*Stenolophus* sp2	2B	2A	2A
3	Sp 3	UN-ID 1*	2A	2B	2A
4	Sp 4	UN-ID 2*	1B	1B	2A
5	Sp 5	*Caelostomus sp*	2A	2B	1A
6	Sp 6	*Stenolophus* sp3	1A	1B	1A
7	Sp 7	UN-ID 3*	1B	1B	1A
8	Sp 8	*Chlaenus sp*	2B	1B	1B
9	Sp 9	*Dicranoncus quadridens*	2A	2A	2B
10	Sp 10	*Loxocrepis cerurales*	1A	1B	2A
11	Sp 11	*Stenolophus* sp1	2B	3A	2B
12	Sp 12	*Paussidae* sp	1B	1B	1A
13	Sp 13	*Drypta lineola*	1B	1B	1B
14	Sp 14	*Scarites sp*	2A	3A	2A
15	Sp 15	*Arhytinus indicus*	2A	1B	1B
16	Sp 16	*Stenolophus* sp4	1B	1B	1B
17	Sp 17	UN-ID 4*	2B	1B	1A
18	Sp 18	*Orthogonius sp*	1A	1A	1A
19	Sp 19	*Dioryche* sp2	2A	1A	1B
20	Sp 20	*Perigona* sp	1B	-	1A
21	Sp 21	UN-ID 5*	1B	1A	-
22	Sp 22	*Metacolpodes nilgherriensis*	3B	1B	2B
23	Sp 23	*Batoscelis* sp1	1A	1B	1A
24	Sp 24	UN-ID 6*	1B	1B	1A
25	Sp 25	UN-ID 7*	3B	1B	1B
26	Sp 26	*Trigonotoma indica*	1B	1B	2A
27	Sp 27	*Galerita orientalis*	1B	1B	1B
28	Sp 28	*Omphra pilosa*	3A	3A	2B
29	Sp 29	*Craspedophorus mandarinellus*	1B	1B	3B
30	Sp 30	*Odocanthus* sp	2A	1B	1A
31	Sp 31	UN-ID 8*	1A	1A	1B
32	Sp 32	*Macrocheilus bensoni*	1A	1B	1B
33	Sp 33	*Amblystomus guttatus*	1B	1B	1B
34	Sp 34	*Archicolliuris bimaculata*	1B	1B	1B
35	Sp 35	*Trigonotoma* sp	1B	-	1B
36	Sp 36	*Lebia* sp	1B	1A	1B
37	Sp 37	*Planets ruficollis*	1A	1A	-
38	Sp 38	*Cyminidis* sp	1C	1B	1B
39	Sp 39	*Planets ruficeps*	1B	1B	1B
40	Sp 40	*Lachnothorax biguttatus*	1B	1B	1B
41	Sp 41	*Brachinus sexmaculatus*	1B	1B	1B
42	Sp 42	*Batoscelis* sp2	1B	1B	1A
43	Sp 43	*Helluodes devagiriensis*	1B	1B	1B
44	Sp 44	*Pheropsophus lissoderus*	1B	-	3B
45	Sp 45	*Pheropsophus bimaculatus*	1B	3B	3B

Class 1A
Insect species that show a sharp well-defined peak in its activity pattern with strongly restricted timing of activity are classified under this category and are referredto as highly seasonal. In few of the species collected at the traps in the three ecosystems exhibited this behaviour of activity pattern through the year. In coffee, cardamom and mixed cropping ecosystems seven, six and 11 species, respectively were categorized under this class of seasonality during 2018-19 (Table 2).

Class 1B
Insect species that show more than one peak in their activity and restricted to certain weeks during this activity period are classified into class 1B. This kind of seasonality was exhibited by most of the insect species across ecosystems. Among the carabid species trapped in coffee, cardamom, and mixed cropping ecosystems, 22, 27 and 18 species of carabid beetles, respectively were classified under this seasonality class (Table 2).

Class 1C
Insects that show a single broad seasonal peak and found to be restricted to certain months during their activity timing are classified under this category. One species each in coffee and cardamom were classified under this group whereas, none of the species in mixed cropping ecosystem was categorized under this class (Table 2).

Class 2A
Insect that occurs through the year and has its activity peaking in one season are classified under this class. In coffee, cardamom and mixed cropping ecosystems, seven, three and seven species, respectively that were trapped could be categorized under this class (Table 2).

Class 2B
This phenomenon occurs through the year with the activity of the insects peaking in more than one seasonal peak. In this class a total of five, two and four species, respectively were found in coffee, cardamom and mixed cropping ecosystems (Table 2).

Class 2C
Insect species with broad seasonal maxima and which occurs through the year are classified under this group. None of the species of carabids from any of the ecosystems were categorized under this group in the study (Table 2). *4.5.7 Class 3A* This group indicates the presence of a species more or less constantly throughout the year. Here one and three species from coffee and cardamom ecosystems respectively were categorized under this class**.** *Omphra pilosa* (sp28) of this class was common in both coffee and mixed cropping ecosystem whereas in cardamom ecosystem, *Scarites* sp (sp14) and *Stenolophus* sp 1 (sp11) were found in addition to *Omphra pilosa* (sp28) (Table 1 and 2).

Table 2: Grouping of collected carabid species under different seasonality classes as per Wolda (1988) [16]

Class	Coffee	Cardamom	Mixed cropping
IA	7	6	11
IB	22	27	18
IC	1	1	0
IIA	7	3	7
IIB	5	2	4
IIC	-	-	-
IIIA	1	3	0
IIIB	2	1	3
IIIC	-	-	-

Class 3B
The insect species which occur in an unpredictable manner and have no relation to the season are classified under this group. Two species from coffee, one species from cardamom ecosystems and three species from mixed cropping ecosystem belonged to this class (Table 1 and 2).

Influence of weather parameters on carabid beetle community
Observed variation in temporal patterns of carabid adult abundance, species richness, and diversity indices of sample wise data of carabid beetle community were correlated with one-week average values of different weather parameters *viz.*, temperature (maximum and minimum), relative humidity (RH1 and RH2) and rainfall.

Influence of weather parameters on carabid abundance
Correlation coefficients of linear correlation analyses of each of the weather parameters with the numbers of carabid (abundance) caught in the traps are depicted in Table 3. In light trap collection, it was observed that, the rainfall and minimum temperature in coffee ecosystem (r= 0.32 and 0.67, respectively) had significant and positive correlation, maximum temperature and RH2 (Relative Humidity) had nonsignificant negative (r= -0.11 and -0.03, respectively) influence while RH1 had positive and non-significant (r= 0.27) effect on the catches of carabid in coffee ecosystem. In cardamom ecosystem only rainfall exhibited significant and positive (r = 0.31) correlation with the abundance of carabids while minimum temperature, RH1, RH2 had non-significant positive (r = 0.17, 0.25 and 0.14, respectively) influence on the carabid abundance. However, maximum temperature had a non-significant negative (r = -0.04) effect on the carabid abundance. In mixed cropping ecosystem, all the weather parameters had non-significant correlation with the carabid abundance. Maximum temperature and RH2 had negative (r = -0.15 and -0.03, respectively) correlation while rainfall, maximum temperature and RH1 had positive correlation (r = 0.17, 0.14 and 0.20, respectively) with the abundance of carabids (Table 3). Further, in case of carabids trapped using pitfall traps only RH2 had positive and significant (r = 0.48) correlation with the carabid abundance while all others *i.e.*, rainfall, maximum and minimum temperature and RH1 had non-significant (r = 0.20, - 0.09, 0.05 and 0.17, respectively) effect on the catches of carabid beetles in coffee ecosystems with negative relation between maximum temperature and abundance while it was positive for other parameters (Table 3). When the pooled data of both the traps were correlated with weather parameters, none of the parameters had significant effect on abundance of carabid beetles in coffee ecosystem. Rainfall, RH1 and RH2 had non-significant positive relation (r = 0.12, 0.27, 0.05) while maximum temperature and minimum temperature had negative non-significant relation (r= -0.12, -0.12) and in cardamom ecosystem none of the parameters had significant relation on abundance of carabid beetles but the carabids showed positive relation for all the weather parameters. Similarly, in mixed cropping ecosystem, except for maximum temperature the abundance of carabids was non significantly related with all other parameters while abundance had negative nonsignificant relation with the rainfall (r = -0.14) (Table 3).

Influence of weather parameters on carabid species richness
The correlation co-efficient values derived for different parameters showed variable results regarding their influence

on carabid species richness (Tables 4). The carabid species trapped by light were not significantly correlated with any of the weather parameters in coffee ecosystem. However, rainfall and RH2 had negative impact (r = -0.18 and -0.00, respectively) while maximum temperature, minimum temperature and RH1 had positive impact (r = 0.11, 0.25 and 0.05, respectively) on carabid species richness. In cardamom ecosystem, minimum temperature (r= 0.41) had positive and significant correlation while all other weather parameters were nonsignificantly correlated with species richness. However, rainfall was negatively correlated (r= -0.00) while maximum temperature, RH1 and RH2 (r = 0.07, 0.20 and 0.24, respectively) had positive correlation. Similar was the case with mixed cropping ecosystem with minimum temperature having significant and positive (r = 0.30) correlation and other weather parameters having non-significant positive correlation with the species caught (Table 4). Further, the number of species collected in pitfall trap on different days of sampling was found to be correlated with weather parameters. In coffee ecosystem, minimum temperature and RH2 (r = 0.29 and 0.37, respectively) were positively and significantly correlated whereas, rainfall had negative correlation (r= -0.00) and other parameters had non-significant positive correlation with carabid species richness. In cardamom ecosystem, all the weather parameters had negative impact on the species richness. This correlation was significant for RH1 and RH2 (r= -0.32 and -0.47, respectively) while it was non-significant for rainfall, maximum temperature and minimum temperature. In mixed cropping ecosystem, none of the weather parameters showed significant correlation with the carabid species recovered. This correlation was negative for maximum temperature (r= -0.20) while it was positive correlation for rainfall, minimum temperature, RH1 and RH2 (Table 4). When the pooled data of both light trap and pitfall trap were correlated with weather parameters, carabid species had positive significant relation with maximum temperature and minimum temperature (r= 0.36, 0.33) while rainfall and RH1 had negative non-significant relation (r= 0.18, -0.02) and RH2 showed positive nonsignificant relation with the carabid species. While in cardamom ecosystem rainfall and RH1 had negative relation (r = -0.07, -0.03), maximum temperature, minimum temperature and RH2 showed non-significant positive relation (r= 0.06, 0.18, 0.00). Similarly, in mixed cropping ecosystem, only maximum temperature showed nonsignificant negative relation (r= -0.06) while rainfall, minimum temperature, RH1 and RH2 showed non-significant positive relation (r= 0.00, 0.10, 0.23 and 0.10) (Table 4).

Discussion

Seasonal fluctuation in arthropod abundances and biomass is observed in many tropical and subtropical regions. This knowledge of seasonal variation is necessary to understand their phenological patterns and life history strategies. In the present study 93, 85 and 90 per cent of total species from each ecosystem *i.e.,* coffee, cardamom and mixed cropping ecosystem showed highly seasonal activity and only few species (n=3, 6, and 4) from the respective ecosystem were active almost throughout the year. According to Wolda classification of seasonality, the carabid beetles caught at Mudigere could be categorized into seven groups *viz.*, Class 1A, Class 1B, Class 1C, Class2A, Class 2B, Class 3A and Class 3B while none of the species were classified under Class 2C and class 3C. The literature pertaining to Wolda classification of seasonality with respect to carabids is nil and hence results of other families of Coleoptera are discussed here. The studies on seasonality of scarabaeoid beetles attracted to light at Mudigere were categorized the beetles into four groups *viz.*, Class 1A, Class 1B, Class 1C, Class 3C (Kumari, 2018) [7] and at GKVK Bangalore, the beetles attracted to light were classified into Class 1A, 1B, 1C, 2A and 2C by Aparna (2015) [1]. From the findings of both Aparna (2015) [1] and Kumari (2018) [7] it is clear that most of the scarabaeoid species did not occur throughout the year indicating the strong seasonal activity exists among scarabaeoids whereas in the present study as the sampling duration was only for eight months, seasonality of all the carabid species could not be rightly inferred. However, most of the carabid species appeared with seasonal maxima and few were found more or less constantly throughout the year which is in slight concurrence with the earlier study. Study conducted by Li *et al*. (2007) [9] on seasonal dynamics of carabid beetles displayed markedly different seasonal dynamics, where seasonal variation in both species and individuals was greater. Catches from June, July and September which are the rainy months accounted for 97 per cent of all specimens caught with regard to species and abundance. The present study is slightly in accordance with the above findings wherein the catches from August to November (monsoon and post monsoon season) accounted for nearly 65 per cent of all specimens. A higher per cent of carabid abundance during monsoon season (April to September) would have been obtained if the sampling was carried from April. Nonetheless, it was observed that nearly 35 per cent of all the carabid specimens were caught during monsoon season *i.e*., during August and September.

Influence of weather parameters on carabid beetle community

The variation in the activity and seasonality of carabid beetles during the sampling period in the three agro ecosystems seems to be dependent on environmental factors *viz*., rainfall, temperature and relative humidity. Carabids caught in light traps showed significant correlations with rainfall and minimum temperature in coffee ecosystem, only with rainfall in cardamom ecosystem whereas in mixed cropping ecosystem abundance did not correlate with any of the weather parameters. Similarly, in pitfall trap carabid abundance significantly correlated with RH2 in coffee, RH1 in mixed cropping ecosystem and maximum temperature, RH1 and RH2 in cardamom ecosystem. From the results it is clearly evident that if not by single parameter, the abundance of carabid beetles was affected by combination of weather parameters. Similar findings by Arun and Vijayan (2014) [2] suggested that the total insect abundance had a significant correlation with the rainfall at a lag of 3 months (r = 0.55), minimum temperature showed a significant negative correlation with the monthly fluctuations in insect abundance (r = – 0.66). Although individually insignificant, abiotic environmental factors such as rainfall, number of rainy days, temperature and humidity in combination showed a significant relation with insect abundance. In the present study the correlation of carabids with minimum temperature can be compared with the study done by Jocque *et al.* (2016) [6] wherein it was observed that abundance and the richness of ground beetles caught by light traps were positively associated with the higher minimum temperatures. Similarly, a study by Ramamurthy *et al*. (2010) [13] suggested that the average temperature varying from 9.3 to 36.7°C showed the most significant relationship with total insects catch (r = 0.36) followed by rainfall for different orders *viz*., Lepidoptera (r = 0.21), Coleoptera (r = 0.41), Hemiptera (r = 0.20), Coleoptera (r = 0.27), Dictyoptera (r = 0.22) and Odonata (r = 0.20. Further, the investigation carried out to explore the correlation of weather parameters with the abundance of arthropods in floricultural ecosystems by Ramya *et al*. (2017) [14] in Tamil Nadu revealed that arthropod population was positively correlated with relative humidity (0.4987) and evening sunshine hours (0.1358), but negatively correlated with maximum temperature (-0.5012) and rainfall (-0.2013). Similarly, light trap collection by Bhattacharyya *et al.* (2017) [3] for a period of seven years at Jorhat also indicated that the catches of scarab beetles are influenced by total rainfall, rainy days, wind speed and evening relative humidity. It was also found that combined effect of maximum temperature, total rainfall and wind speed had the maximum influence on their emergence. Hence the current study seems to agree with the results of the studies conducted at different parts of the country mentioned above where the abundance of beetles is affected by various weather parameters individually or in combination. Thus, seasonality appears to be a response to changes in the weather parameters like rainfall, temperature and humidity.

Table 3: Correlation of weather parameters with carabid individuals encountered in the three ecosystems of Mudigere

Traps employed	Weather parameters	Coffee	Cardamom	Mixed cropping
UV light	Rainfall	0.32*	0.31*	0.17
	Maximum temperature	-0.11	-0.04	-0.15
	Minimum temperature	0.67*	0.17	0.14
	RH1	0.27	0.25	0.20
	RH2	-0.03	0.14	-0.03
Pitfall	Rainfall	0.20	-0.21	0.09
	Maximum temperature	-0.09	0.37*	-0.23
	Minimum temperature	0.05	-0.09	0.03
	RH1	0.17	-0.30*	0.28*
	RH2	0.48**	-0.44**	0.09
UV light and pitfall together	Rainfall	0.12	0.10	0.14
	Maximum temperature	-0.12	0.004	-0.14
	Minimum temperature	-0.12	0.19	0.05
	RH1	0.27	0.14	0.26
	RH2	0.05	0.02	0.01

* Correlation is significant at the 0.05 level (1-tailed).
** Correlation is significant at the 0.01 level (1-tailed).

Table 4: Correlation of weather parameters with carabid species encountered in the three ecosystems of Mudigere

Traps employed	Weather parameters	Coffee	Cardamom	Mixed cropping
UV light	Rainfall	-0.186	-0.008	0.00
	Maximum temperature	0.117	0.075	0.00
	Minimum temperature	0.257	0.413**	0.30*
	RH1	0.059	0.202	0.25
	RH2	-0.005	0.245	0.06
Pitfall	Rainfall	-0.005	-0144	0.02
	Maximum temperature	0.230	-0.004	-0.20
	Minimum temperature	0.294*	-0.112	0.04
	RH1	0.023	-0.328*	0.19
	RH2	0.378*	-0.470**	0.05
UV light and pitfall together	Rainfall	-0.186	-0.078	0.02
	Maximum temperature	0.360*	0.069	-0.06
	Minimum temperature	0.334*	0.187	0.10
	RH1	-0.020	-0.036	0.23
	RH2	0.237	0.008	0.10

* Correlation is significant at the 0.05 level (1-tailed).
** Correlation is significant at the 0.01 level (1-tailed).

Conclusion
From the present study it can be inferred that, the carabid beetles caught at Mudigere could be categorized into eight groups *viz.*, Class 1A, Class 1B, Class 1C, Class 2A, Class 2B, Class3A, Class 3B and Class 3C according to Wolda's classification of seasonality. None of the carabids could be grouped into Class 2C, as the beetle activity did not show a broad seasonality throughout the sampling period also carabid species collected had highly seasonal activity and very few were more or less observed in all the seasons. Significant correlation between abundance and different weather parameters did not exist for pooled data of light and pitfall traps in any of the three ecosystems whereas species richness was significantly correlated with maximum and minimum temperature in coffee ecosystem. Similarly, with respect to light and pitfall trap collections all weather parameters had significant influence on adult activity in at least one of the three ecosystems whereas for species richness minimum temperature, RH1 and RH2 were significantly correlated indicating rainfall, temperature and relative humidity had significant effect on the activity of the carabid community in all the three locations.

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