Mysore J. Agric. Sci., 51 (2) : 287-296, 2017

Diversity of Scarab Beetles Attracted to Light Traps in Two Perennial Agro-ecosystems of Mudigere

M. H. Suchithra Kumari and A. R. V. Kumar
Department of Agricultural Entomology, College of Agriculture, UAS, GKVK, Bengaluru-560 065
E-mail: mhsuchithra@gmail.com

Abstract

The activity pattern of scarabaeoid beetles was studied at Mudigere in two perennial crop ecosystems*viz*., Cardamom and coffee,for a period of two years from January 2015 to December 2016by setting up light traps fitted with 8 watt Philips Actinic BL UV tubes. The results indicated that the activity pattern of scarabaeoid beetles in both the ecosystems were highly scattered and distributed year round. However, moving averages indicated that two significant peaks of activity could be broadly identified within each year for the scarabs in the two locations. The most speciose family of the superfamily Scarabaeoidea attracted to light was Scarabaeidae. Scarabaeidae and Hybosoridae were common to both the ecosystems in both the years.By number of specimens, a total of 1235 (Mean= 8.64 ±15.22 per sample) and 1682 (13.57 ±26.53 per sample) were recovered from both the locations during 2015 and 2016, respectively that contributed to a total of 2917 specimens of scarabs distributed among 74 species.Activity and diversity parameters like abundance, species richness, Shannon-Weiner index and Simpson's reciprocal index were strongly inter-correlated. In both the years, cardamom was observed to be richer than coffee ecosystem, suggesting the potential impact of the differential management practices on the richness of the two ecosystems.

Keywords: Scarabaeidae, light trap, cardamom, coffee, abundance, species richness, diversity

Scarabaeoidea constitutes one of the largest cosmopolitan superfamily of Coleoptera consisting of ~31,000 species worldwide. Historically, scarabaeoids have served as objects of religion, culture, aesthetic appreciation and economic significance. In particular the dung beetles have attracted the attention of humans since the early Egyptian civilisation. But yet, surprisingly, little is known about the biodiversity and life histories of the majority of the world species. Scarabs also called as lamellicorn beetles are numerous, worldwide in distribution and both the phytophagous and non-phytophagous species are of significant economic importance, making them interesting subjects for ecological studies. The greatest diversity of scarabaeoid species occurs in the tropics, with the majority of known species represented by the family Scarabaeidae. Comprehensive research on scarab beetle diversity of central India was made by Chandra and Gupta (2012 a and b). However, their study was limited to central part of India and was largely an attempt to address the faunal composition from the taxonomic point of view. Studies on the diversity and abundance of scarabs were also attempted in Maharashtra (Thakare *et al*., 2011) especially in Kolkas region of Melghat Tiger Reserve and in Northeast India (Bhattacharya *et al*., 2017). Some work on the fauna of south India has been attempted by Sabu *et al.* (1995, 2006) and also on seasonality and community ecology (Anon., 2013-14; Aparna, 2015 and Kimondiu *et al*., 2017). Yet, none of these studies made attempts to assess the relative variability in the diversities of many of these groups at different locations.

Sampling is the basis of documenting the spatial distribution of species or assessing changes in ecosystem structure, composition and function. It is important to use simple and most effective methods to obtain an estimate of diversity and relative abundance of species. Different methods have been used for collecting beetles for research purposes and for preparing inventories depending on their biology and host range (Missa *et al*., 2009). Many groups of beetles are positively phototrophic and can be best

sampled using light traps as is the case with scarabs. It has been reported that light source wave lengths (Viraktamath and Kumar, 2005) and hours of sampling influence scarab beetle catches (Lopez *et al*., 2011). The data provided by light trap catches could throw light on diversity and activity patterns of insects. In this study an attempt has been made to assess the diversity and abundance of scarabaeoid beetles supported by two perennial agro-ecosystems in Mudigere using light traps. Efforts have also been made to assess the impact of different abiotic factors on abundance, species richness and diversity of scarab beetles.

Material and Methods

The study was carried out in Mudigere, Chikkamagalur District, Karnataka State, India which is geographically located at 13°08' N latitude and 75°38' E longitude and at an altitude of 915 meters above sea level. Mudigere falls under the Hilly zone (Agro Climatic Zone 9) of Karnataka and receives an average annual rainfall of about 2500 mm.

Two perennial agro-ecosystems *viz*., cardamom and coffee were selected for sampling of scarab beetles. The samples were collected by setting up funnel and vane type of light traps fitted with two 8 watt Philips Actinic BL UV tubes (12" long- 16 % UVA) in each ecosystem, so that the light dispersed in all the 360 degrees, horizontally. These light traps were run at periodic intervals on specified dates for 12 hours from 6.00 p.m. to 6.00 a.m. next day morning. The light traps were run for a period of two years from January 2015 to December 2016. The insects attracted to light were collected in a container placed at the bottom of the light trap provided with salt water and soap solution as the killing agent. The trap catches were brought to the laboratory washed with fresh water, air dried and sorted to take out all scarabs. Larger scarabaeoid beetles were easily separated by handpicking and smaller ones were separated under a stereo-zoom microscope. All the specimens were further sorted into different morpho-types and assigned a code. Each morpho-type, in principle represented a taxonomic species. These morpho-types were identified by running the available keys and later the identified morpho-types were classified into their respective families, subfamilies and tribes and their numbers counted. The representatives of the morpho-types were pinned and the rest were stored in paper packets with proper labelling for further examination. Data on day wise catches were tabulated and analysed suitably to understand the patterns of activity, diversity, *etc*.

Results and Discussion

Patterns of activity of Scarabaeoids

The two agro-ecosystems were observed to differ in their ability to attract the scarab beetles to the light trap. As many as 143 and 124 nights of trapping was done during the year 2015 and 2016, respectively, in both cardamom and coffee ecosystems. A total of 1235 and 1682 individuals were collected during this period in the two ecosystems. Scarabs collected were 545 and 773 individuals in cardamom and 690 and 909 individuals in the coffee ecosystem during 2015 and 2016, respectively (Table I).

Considering the pattern of catches by individuals and numbers of species in the two ecosystems, it was observed that the trends were not clearly discernible. Therefore, three sample means were used to check for potential patterns. The three sample means for activity of scarabs in the two ecosystems could indicate roughly similar pattern across the years and across the two ecosystems. In all the cases, the two broad peaks could be made out. The first one roughly coincided with the beginning of the rainy season and the second one with the end of the rainy season (Figs. 1 to 4). However, in coffee ecosystem, the 2015 samples for individuals indicated an apparent single early monsoon peak. The trends were more or less similar across the years in both the systems held for both individuals and for the numbers of species. These patterns were similar to those observed earlier by Aparna (2015) in Bengaluru.

Abundance, Species Richness and Diversity of scarabaeoids in the two locations

As many as 545 (Mean = 8.93 ± 11.31 per sample) Scarabaeoidea specimens were recovered through light trap studies at the cardamom farm that also yielded 65 species (Mean = 4.38 ± 4.10 per sample) during 2015. At the coffee plantation during

TABLE I

Mean catches by numbers, species and diversity indices of scarabaeoid beetles collected at the two different locations of Mudigere during the year round light trapping in 2015 and 2016

Ecosystem	Year	Particulars	Total	Minimum	Maximum	Aver-age	SD
Cardamom	2015 (N=61)	No. of individuals	545	0	45	8.934	11.311
		No. of species	65	0	17	4.377	4.100
		Shannon-Weiner index	-	0	2.493	1.009	0.712
		Simpson's reciprocal index	-	0	10.256	3.078	2.175
	2016 (N=65)	No. of individuals	773	0	78	11.892	16.575
		No. of species	65	0	18	4.646	3.982
		Shannon-Weiner index	-	0	2.354	1.002	0.706
		Simpson's reciprocal index	-	0	7.813	3.113	2.074
Coffee	2015 (N=82)	No. of individuals	690	0	132	8.415	17.639
		No. of species	54	0	18	3.573	4.175
		Shannon-Weiner index	-	0	2.432	0.805	0.817
		Simpson's reciprocal index	-	0	10.667	2.509	2.669
	2016 (N=59)	No. of individuals	909	0	231	15.407	34.386
		No. of species	54	0	15	4.763	3.91
		Shannon-Weiner index	-	0	2.415	1.054	0.753
		Simpson's reciprocal index	-	0	10.256	3.263	2.206
Cardamom and Coffee together	2015 (N=143)	No. of individuals	1235	0	132	8.363	15.218
		No. of species	73	0	18	3.916	4.148
		Shannon-Weiner index	-	0	2.493	0.892	0.778
		Simpson's reciprocal index	-	0	10.256	2.752	2.478
	2016 (N=124)	No. of individuals	1682	0	231	13.565	26.526
		No. of species	74	0	18	4.702	3.932
		Shannon-Weiner index	-	0	2.415	1.027	0.773
		Simpson's reciprocal index	-	0	10.256	3.184	2.130

Note: SD = Standard deviation; N = No. of samples

the year 2015, 690 (Mean = 8.42 ± 17.64 per sample) scarabs were collected that accounted for 54 species (Mean = 3.57 ± 4.18 per sample). Similarly, during 2016, in cardamom, 773 (Mean = 11.89 ± 16.58 per sample) specimens were recovered that contributed 65 species (Mean = 4.65 ± 3.98 per sample). In coffee, during 2016, 909 (Mean = 15.41 ± 34.39 per sample) specimens were recovered that included 54 species (Mean = 4.76 ± 3.91 per sample) (Table I).

In all, 267 traps were run in the two locations over the two year period. This resulted in recovery of 2917 specimens of scarabs that were distributed among 74 species. By number of specimens, both the ecosystems were matching (mean values per trap) during 2015 while in 2016 more specimens were caught in coffee ecosystem. Nevertheless, the high standard deviation suggested a high degree of variability in trap catches in coffee ecosystem

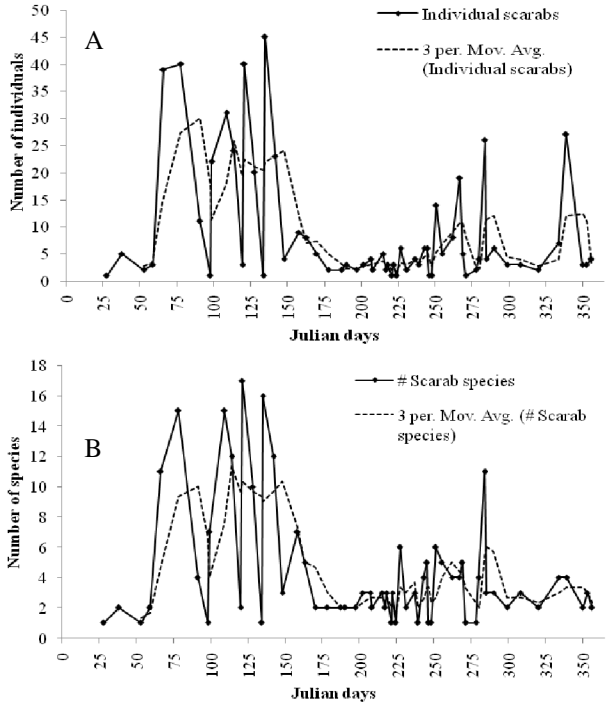

Fig. 1: Number of individuals (A) and number of scarab species (B) caught at light trap in cardamom during the year 2015 at Mudigere.

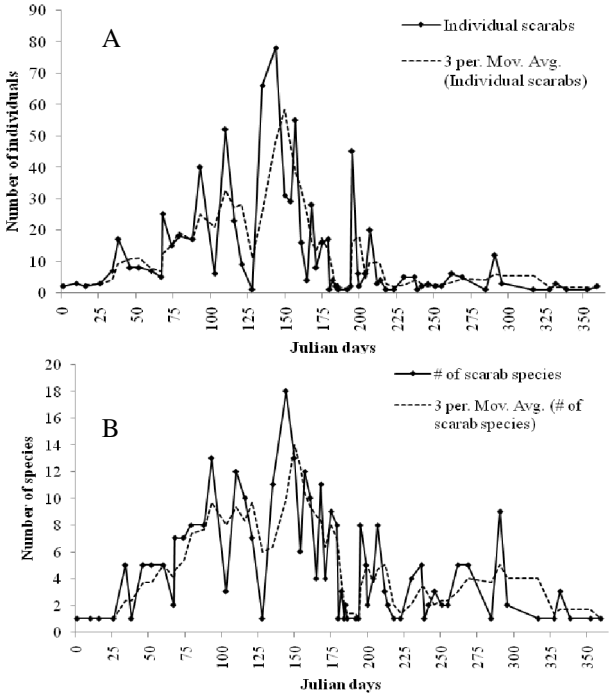

Fig. 3: Number of individuals (A) and number of scarab species (B) caught at light trap in cardamom during the year 2016 at Mudigere.

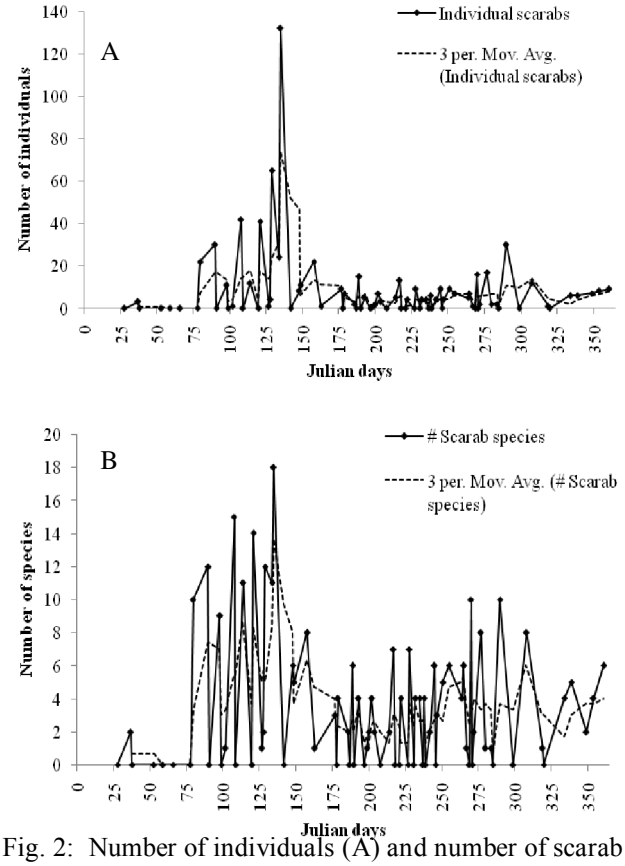

Fig. 2: Number of individuals (A) and number of scarab species (B) caught at light trap in coffee during the year 2015 at Mudigere.

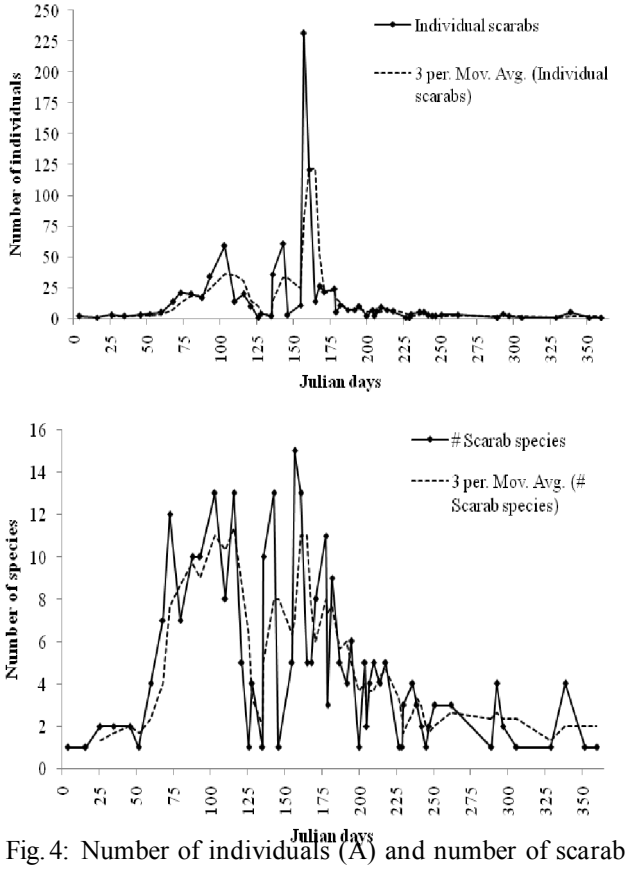

Fig. 4: Number of individuals (A) and number of scarab species (B) caught at light trap in coffee during the year 2016 at Mudigere.

compared to cardamom. Further interestingly, the number of species recovered remained constant for both the years across the two locations irrespective of the variable sample numbers and the mean abundances per trap. In both the years, the cardamom system accounted for higher species richness and greater species diversity compared to coffee system.

Species richness and taxonomic representation

In all 73 species were collected from the two ecosystems with 65 in cardamom and 54 in coffee ecosystem with 46 species being common to the two ecosystems. Nineteen species were unique to cardamom and eight unique to coffee system during 2015. While, 74 species were collected from the two ecosystems during 2016 with 65 in cardamom and 54 in coffee ecosystem with 45 species being common to the two ecosystems; 20 species were unique to cardamom and nine were unique to coffee ecosystem (Table I and II).

Diversity, species richness and abundance of many groups of insects are expected to remain stable or increase in agro-forestry systems, when supported by shade trees and relatively open canopy (Bos *et al.,* 2007). Both cardamom and coffee ecosystems fit this agro-forestry models, as in both the systems the shade trees are available. This aspect was not verified here in relation to forest system, but yet, it is intriguing to find significant differences between the numbers of species in the two systems. Generally non-phytophagous dung beetles are the ones that are expected to suit this idea of stability or increased diversity in systems where the shade trees are prevalent. Relative diversity of the two groups, phytophagous and non-phytophagous scarabs, was not studied here. But yet it is interesting to observe that two perennial, apparently similar agro-ecosystems, may not be similar in the scarab community composition despite being reasonably close (less than a km). The definitive reasons for this difference would

TABLE II

Taxonomic representation of scarabaeoid beetles collected at the light traps in cardamom and Coffee ecosystems of Mudigere during 2015 and 2016

Family	Cardamom								Coffee							
	2015				2016				2015				2016			
	No. of subfamilies	No. of tribes	No. of genera	No. of species	No. of subfamilies	No. of tribes	No. of genera	No. of species	No. of subfamilies	No. of tribes	No. of genera	No. of species	No. of subfamilies	No. of tribes	No. of genera	No. of species
Scarabaeidae	7	13	24	58	6	18	25	59	6	15	26	53	5	12	21	50
Bolboceratidae	1	1	1	1	1	1	2	2	0	0	0	0	0	0	0	0
Hybosoridae	1	1	2	2	1	1	1	1	1	1	1	1	1	1	1	1
Lucanidae	1	1	1	1	1	1	1	1	0	0	0	0	1	1	1	1
Passalidae	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1
Trogidae	1	1	1	2	1	1	1	2	0	0	0	0	1	1	1	1
Total	**12**	**18**	**30**	**65**	**10**	**22**	**30**	**65**	**7**	**16**	**27**	**54**	**9**	**16**	**25**	**54**
Commom Sp.				46				45				46				45
Unique Sp.				19				20				8				9

be worth exploring through further analyses of the data in comparison with the ecosystem parameters.

A broad taxonomic representation of the scarabaeoid beetles attracted to light in cardamom and coffee during 2015 and 2016 are represented in Table II. It is evident that, the most speciose group was Scarabaeidae, while, other families were represented only in small numbers of species. Six and five families of scarabs were collected from cardamom ecosystem during the two years while only two and five families were collected from coffee ecosystem in both the years. Bolboceratidae was not recorded in coffee ecosystem during 2015 and 2016 while Scarabaeidae and Hybosoridae were common to both the ecosystems in both the years.

Interrelationships between weather parameters and the trap catch data

Using the data of abundance and species numbers caught over the sampling days, an attempt was made to understand the relationships between weather parameters and the various parameters of trap catches and diversity. The Pearson product moment correlation coefficients were worked out for daily catch abundances, species richness, Shannon-Weiner index, Simpson's reciprocal index and climatic variables for both the years (Tables III and IV).

In cardamom ecosystem, both during 2015 and 2016, all the activity parameters such as abundance, species richness, Shannon-Weiner index and Simpson's index were found to be strongly intercorrelated with high coefficients of determination (>70 % ; Table III). All the values were positive. However, the weather parameters considered such as rainfall, maximum daily temperature, minimum daily temperature, maximum daily relative humidity, minimum daily relative humidity were found to vary in their effect on the scarab activity parameters from year to year. The year to year variation was intractable and it was difficult to draw any strong conclusion on

TABLE III

Matrix for correlation between the weather parameters and abundance and diversity parameters in cardamom ecosystem of Mudigere during 2015 and 2016. (The upper triangle represents the data for 2015 and the lower triangle represents the data for 2016)

	Rainfall	Max. temperature	Min. temperature	Max. Relative humidity	Min. Relative humidity	Number of individuals	Number of species	Shannon-weiner index	Simpson's reciprocal index
Rainfall	1.00	-0.077	0.071	0.077	0.148	0.032	0.077	0.089	0.032
Max. temperature	-0.426*	1.00	-0.342*	0.00	-0.525*	0.481*	0.469*	0.314*	0.349*
Min. temperature	-0.134	0.374*	1.00	0.585*	0.699*	-0.044	0.00	0.063	0.031
Max. Relative humidity	0.088	-0.347*	-0.394*	1.00	0.418*	0.00	0.109	0.164	0.268*
Min. Relative humidity	0.281*	-0.723*	-0.170	0.554*	1.00	-0.300*	-0.202	-0.044	-0.126
Number of individuals	-0.054	0.317*	0.207	0.089	0.044	1.00	0.923*	0.723*	0.673*
Number of species	-0.161	0.317*	0.272*	0.070	0.070	0.863*	1.00	0.883*	0.870*
Shannon-Weiner index	-0.212*	0.219*	0.209	0.118	0.104	0.594*	0.880*	1.00	0.927*
Simpson's reciprocal index	-0.181	0.194	0.187	0.054	0.089	0.492*	0.837*	0.941*	1.00

Note: * Significance at 0.05 (No. of samples 2015 = 61 and 2016 = 65)

the effect of any of the weather parameters on the activity and diversity parameters of the scarabs in cardamom ecosystem. Soil moisture is expected to be the single most influencing factor on the activity of scarabs. However, rainfall, anticipated to be the proxy for the soil moisture state was not found to be correlated with the activity of the scarabs in both the years in caradamom ecosystem (Table III).

In coffee ecosystem, although the various activity and diversity parameters considered were positively intercorrelated during the two years of survey, the coefficients of determination were highly variable and quite low. A case in point is the lack of good association between the abundance and the Simpson's reciprocal index during 2016. Considering the various weather parameters and their effect on the activity and diversity parameters in coffee ecosystem, the trends were unpredictable between the year. As was the case with caradamom system, the commonality in the effects of the weather parameters from year to year on the scarab activity was not possible to be clearly deduced. As a corollary, even in coffee ecosyetm it was noted that the rainfall had no effect on the activity of scarabs in both the years (Table IV).

The relationships between species abundance and factors driving the biodiversity are often largely unknown (Terradas *et al*., 2004). However, it has been proven that many variables are statistically related to species richness and distribution: *e.g.*, climate, altitude (Kessler, 2009), latitude (Andrew and Hughes, 2005), physical factors of the soil, disturbance degree (Davis and Philips, 2009) and temporal dynamics (Gobbi *et al.*, 2007). Among these, rainfall is an important factor that influences variation in the insect activity in tropics (Wolda, 1988) and semi-arid ecosystems (Liberal *et al*., 2011). The activity of scarab beetles in tropical regions is often synchronized or maximized in line with rainfall (Aparna 2015; Bhattacharyya *et al*., 2017).

TABLE IV

Matrix for correlation between the weather parameters and abundance and diversity parameters in coffee ecosystem of Mudigere during 2015 and 2016. (The upper triangle represents the data for 2015 and the lower triangle represents the data for 2016)

	Rainfall	Max. temperature	Min. temperature	Max. Relative humidity	Min. Relative humidity	Number of individuals	Number of species	Shannon-weiner index	Simpson's reciprocal index
Rainfall	1.00	-0.151	0.054	0.089	0.228*	-0.054	-0.063	0.00	0.00
Max. temperature	-0.039	1.00	-0.386*	0.070	-0.508*	0.322*	0.316*	0.144	0.122
Min. temperature-	-0.044	0.368*	1.00	0.192	0.577*	-0.144	-0.077	0.044	0.054
Max. Relative humidity	0.288*	-0.407*	-0.192	1.00	0.408*	0.077	0.094	0.077	0.063
Min. Relative humidity	0.378*	-0.692*	-0.054	0.595*	1.00	-0.044	-0.031	0.031	0.063
Number of individuals	-0.063	0.00	0.209	0.054	0.189	1.00	0.802*	0.466*	0.316*
Number of species	0.00	0.192	0.519*	0.031	0.109	0.684*	1.00	0.876*	0.758*
Shannon-Weiner index value	0.114	0.154	0.498*	0.122	0.118	0.260*	0.824*	1.00	0.899*
Simpson's reciprocal index	0.054	0.240	0.475*	0.00	0.00	0.094	0.741*	0.904*	1.00

Note: * Significance at 0.05 (No. of samples 2015 = 82 and 2016 = 59)

Soil dwelling scarabs are expected to be greatly impacted by the soil moisture conditions. In particular, in tropical situations such as Mudigere, where clear cut dry seasons are followed by the rainy months, it was anticipated that the effect of rainfall would be strongly borne out on the scarb abundace and diversity (Wolda, 1988). Despite a two year long effort, the present study however, did not bear out any such strong effect. Several factors might contribute for this situation. Mudigere being a heavy rainfall area (>2500 mm per annum) the initial rains may sufficiently provide the wetness for a continued relatively stable wet conditions for the activity of the scarabs thus later rains may have slight impact. Such a situation is a possibility, as in studies carried out at Bengaluru clearly indicated two peaks of activity one during the beginning of the rainy season and later at the end of the rainy season (Aparna, 2015 and Anon., 2014). Broad similar trends were evident in the present study also for abundance and species richness. This could potentially be a possibility as scarabs as a community represents variable life history situations. Most phytophagous species require moisture for their activty during their larval periods. As a result, the adults may tend to remain active during the early part of the season allowing an extended activity period for the larvae. On the contrary, the non-phytophagous species may rely not just on soil moisture state but also on the moiture state of the available food or micro habitat such as dung. This might permit them to remain active for an extended period and further as these resources are likely to be ephemeral, they may be relatively smaller in size with shortened life cycle duration. An assessment of the relative body sizes of the two communities and their activity breadths would possibly provide an insight into this aspect.

Wolda (1978) proposed two general hypotheses to explain the variability in activity patterns of tropical insects: climatic predictability and seasonal variation of food resources. The former suggests that populations should fluctuate less in areas where the climate is more predictable. The latter argues that insect numbers should be directly related to seasonal variations depending on the availability of food resources. In tropics, among all climatic factors (temperature, photoperiod, rainfall and wind speed) rainfall and variation in the availability of food resources are the important factors in triggering seasonal activity of insects (Frolov and Akhmetova, 2013; Medina and Lope, 2014; Lopez *et al*., 2010). Temperature affects the insect activity and diversity on a long term basis than short term. Thus clearly the increasing temperatures of the globe are a concern in the context of climate change (Kimondiu *et al*., 2017). The seasonality of dung beetle assemblages constantly changes and the relative abundance of individual species changes along with change in the weather parameters (Kakkar and Gupta, 2009). Thus the general idea of variable activity of phytophagous and non-phytophagous species that revolves around the more predictable monsoon seems to be evident in the present study also. However, the non-phytohagous species such as the dung feeding scarabs are likely to remain affected by the prevailing weather factors. In the present study, the two communities are mixed up and thus clear cut conclusions are difficult to be drawn. Yet, further analyses of the data may help generate better ideas.

The present study indirectly suggests possibility of the scarab activity being controlled by the rainy season in Mudigere. The two generalized peaks observed for abundance and species richness fit the two ends of the monsoon period in Mudigere. A second important aspect that could be noted was the higher species richness in cardamom ecosystem. Potentially this reflects the relative impact of the management system between the coffee and the cardamom. Cardamom is more cared for and has greater degree of disturbance and soil enrichment while relatively coffee is less cared for and possibly promotes hardier species. It is felt that more detailed analyses of the data may help improve the ability to sort out the effects of various weather parameters, in particular the rainfall on the activity of various ecological guilds within the scarabs. Further, as many scarabs are pestiferous, it is suggested that monitoring the community would help improve the management practices.

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(*Received :* May, 2017 *Accepted :* June, 2017**)**