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Taxonomic Diversity of Carabid Beetles in the Agricultural Landscape under Hot Semi-Arid Climate in Mandi Bahauddin, Punjab, Pakistan

Mubashar Hussain*, Habiba Razaq, Muhammad Faheem Malik, Kiran Aftab, Jaweria Riaz and Somia Liaqat

Department of Zoology, University of Gujrat, Gujrat, Punjab, Pakistan

ABSTRACT

Ground beetles are recognized as important biological control agents and environmental indicators that inhabit a wide range of habitats. The diversity of carabid beetles in Pakistan has not yet been studied extensively, despite their diversified ecological roles. In the present study, the ground beetle communities from three subdivisions of district Mandi Bahauddin (Phalia, Malakwal and Mandi Bahauddin) were sampled by handpicking and placing pitfall traps from August 2020 to July 2021. A total of 4008 specimens were collected which belonged to 18 species, 11 genera, nine tribes, and five subfamilies. Data were analyzed with Similarities Percentage (SIMPER) analysis and diversity indices were compared among those three croplands. We found that *Pheropsophus lissoderus* was the most abundant and dominant species in all three study sites whereas *Brachinus bilineatus* and *Galerita lecontei* were recorded only in tehsil Phalia, *Pheropsophus verticalis,* and *Dioryche subrecta* in Malakwal. Pheropsophus was the most abundant and dominant genus representing six species in all three sites. Overall Shannon index (H:2.545), Simpson index (1-D:0.893), and evenness (e^H/S: 0.709) indicated relatively greater carabid species richness in district Mandi Bahauddin. Comparative values of indices showed similar patterns of species diversity and evenness i.e. Mandi Bahauddin (1-D = 0.902, e^H/S = 0.866), followed by Malakwal (1-D = 893, e^H/S = 0.769), and Phalia (1-D = 0.876, e^H/S = 0.712). Similarity Percentage analysis by using the Bray-Curtiss dissimilarity matrix showed the highest overall dissimilarity between Malakwal and Mandi Bahauddin (42.68%), followed by Phalia, and Malakwal (28.88%), whereas the least dissimilarity was recorded between Phalia and Mandi Bahauddin (26.53%). We conclude that carabid beetles in district Mandi Bahauddin have relatively greater species richness. The study reports *Poecilus versicolor* for the first time from Pakistan.

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Authors' Contribution
MH and HR presented the concept of the study, and performed data collection and identification. HR, JR, SL and KA helped in identification specimen and writing-editing. MFM and MH critically reviewed the manuscript.

Key words
Brachininae, Carabidae, Croplands, Diversity, Mandi Bahauddin

INTRODUCTION

The ground beetles (Carabidae: Coleoptera) also called carabid beetles represent approximately 40,000 described species (Riddick and Capinera, 2008) that inhabit almost all terrestrial habitats, especially in agroecosystems (Della Rocca *et al*., 2021). Carabid beetles consume several agricultural pests and weeds (De Heij and Willenborg, 2020), and their diversity in agroecosystems is mainly related to the microclimate rather than crop type (Reich *et al*., 2020). Ground beetles are key species in agricultural landscapes contributing significantly to the ecosystem as natural enemies of many pest species (Piotrowska *et al*., 2020).

Several beneficial insect species have shown a decline in the population due to agricultural intensification (Forister *et al*., 2016; Raven and Wagner, 2021; van der Sluijs, 2020; Wepprich *et al*., 2019). Agricultural intensification (Rusch *et al*., 2016), climate change (Brandmayr and Pizzolotto, 2016), and habitat fragmentation (Niemelä, 2001) affect carbid diversity. Landscape assessments and consequently re-establishment of semi-natural habitats contribute significantly to detecting and minimizing biodiversity losses, which will be beneficial to agricultural production (Raven and Wagner, 2021; Wang *et al*., 2021). Extensive works at global, regional and local assessment of carabid beetles assemblages have been made to explore taxonomic diversity in different agroecosystems (Rischen *et al*., 2021; Rouabah *et al*., 2015; Zajicek *et al*., 2021; Zou *et al*., 2015). The carabid fauna has not been explored from different agricultural zones of Pakistan though some work on diversity were reported from different parts of

* Corresponding author: dr.mubashar@uog.edu.pk
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Pakistan (Hussain *et al*., 2021). Some research work on the distribution and diversity of species was conducted in different parts of the country i.e. carabid fauna segregated from the fauna of British India (Kazi *et al*., 2016), district Haripur (Bibi and Rehman, 2020), checklist of ground beetles (Azadbakhsh and Rafi, 2017), Mekran Division (Khatri *et al*., 2016), Mansehra Division (Mishkatullah, 2018), ecological zones of Sukkur (Soomro *et al*., 2021), and upper Sindh plains (Sahito *et al*., 2021). In Mandi Bahauddin, being an agricultural district, baseline data on the carabid diversity has not been explored yet. The composition and density of carabid taxa vary according to environmental conditions like temperature and rainfall, edaphic factors, and the communities. This asserts the assessment of carabid communities at local levels which would be helpful in the analysis of species diversity to evaluate the impact of environment within the habitat concerned. The objective of this study is to explore the community patterns of carabid beetles in the agricultural landscape of district Mandi Bahauddin.

MATERIALS AND METHODS

Study area

Mandi Bahauddin (32.4105° N, 73.3709° E; 220 m asl) is located in the province of Punjab, Pakistan. It has three subdivisions (Tehsils) i.e. Mandi Bahauddin, Phalia and Malakwal. The district has predominantly agricultural economy. The district is located between two major rivers Jhelum and Chenab and is commonly known as Chajjdoab. Mostly irrigated through Lower Jhelum Canal and partly through Upper Jhelum Canal. The climate of this district is classified as BSh (hot semi-arid climate**)** by the Koppen-Geiger system (Ranjha *et al*., 2018). The climate of the district is moderate, hot during summer, and cold during winter. The highest temperature in summer may rise to 48 °C and may fall below 3 °C in winter. Generally, weather reverberates with Islamabad with an average rainfall of 388 millimeters. Most of the land near this town is arable and residents are involved in agriculture. Wheat (*Triticum aestivum*), rice (*Oryza sativa*), sugarcane (*Saccharum officinarum*), corn (*Zea mays*) and potato (*Solanum tuberosum*) are commonly cultivated crops. Wild plants include bhakra (*Tribulus terrestris*), khabal (*Cynodon dactylon*), baer (*Ziziphus jujuba*), pipal (*Ficus religiosa*), kala toot (*Morus nigra*), Dherak (*Melia azedarach*) and chibbar (*Cucumis melo* var. *agrestis*) (Nisar *et al*., 2011).

Collection of specimens

Adult carabid beetles were collected fortnightly from August 2020 to July 2021 by hand picking and pitfall traps. Three transects of 500 m length were placed for data collection. Ten pitfall traps were built at 150 m distance along transects in all locations (Andrade *et al*., 2011; Larsen and Forsyth, 2005). Plastic flasks were used to prepare the pitfall traps and then burrowed into the soil with their edge leveled with soil surface. Vinegar was used as an attractant in pitfall traps and traps were emptied after 72 h (Steward *et al*., 2017).

Identification of specimens

The morphological characters of preserved samples were identified under dissecting microscope, using available taxonomic identification keys, pictorial keys and online resources (Abdullah and Azmir, 2021; Choate, 2001; Klimaszewski and Watt, 1997).

Statistical analysis

Species richness measures biodiversity by taking into account the number of species in a given area. Margalef's diversity index and Menhinick's diversity indices report species richness whereas Richness–Evenness indices like Shannon–Wiener diversity index, Brillouin index, Fisher's alpha, Pielou index, and Simpson's index (Hussain *et al*., 2021; Magurran, 2004). We calculated ecological indicator these indices for measuring species diversity by using PAST3 software (Kumar *et al*., 2022). We also performed similarity of percentages analysis (SIMPER) to identify the species which were contributing the most to differences in communities spatiotemporially (Umar *et al*., 2022).

RESULTS

Species composition

In our study, 4008 ground beetle individuals were collected, belonging to 11 genera and 18 species and representing five subfamilies, nine tribes. Brachininae (7 species) and Harpalinae (6 species) were two most dominant subfamilies. Genus *Pheropsophus* (6 species) was dominant genus in the study area (Table I). We considered all those species dominant comprising over 5% were considered dominant species whereas those who showed at least 1% abundance were designated as common species in a given habitat. *P. lissoderus, C. auropunctatum, C. herbacea, C. platicollis, P. versicolor, S. quinquepustulatus, P. africanus, P. catoirei, P. h. hilaris* and *S. quadriceps* were dominant species in tehsil Mandibahuddin. Five species were amongst dominant species in Malkwal tehsil (*P. africanus, P. catoirei, P. lissoderus, P. versicolor,* and *S. quinquepustulatus*). In Phalia, six species occurred with greater than 5 % abundance (*P. africanus, P. catoirei, P. lissoderus, Chlaenius pictus, P. versicolor,* and *S. quinquepustulatus*) and these were designated as dominant

species in this habitat.

Table I. Relative abundance (%) of carabid beeles (Carabidae: Coleoptera) in different tehsils of district Mandi Bahauddin.

Subfamilies/ Tribe/ Species	Relative abundance (%)		
	Phalia	Malak-wal	Mandi Bahauddin
Subfamily: Brachininae **Tribe:** Brachinini			
Brachinus bilineatus	2.48	--	--
Pheropsophus africanus	8.01	6.25	6.70
P. catoirei	12.98	14.63	9.86
P. hilaris hilaris	4.81	3.05	5.69
P. hilaris sobrinus	3.61	2.44	3.79
P. lissoderus	27.64	23.46	21.24
P. verticalis	--	4.62	--
Subfamily: Carabinae **Tribe:** Carabini			
Calosoma auropunctatum	3.85	4.88	5.31
C. inquisitor	2.40	4.88	3.03
Subfamily: Cicindelinae **Tribe:** Cicindelini			
Cicindela herbacea	3.37	4.27	5.31
Subfamily: Harpalinae **Tribe:** Chlaeniini			
Chlaenius pictus	9.13	3.81	4.93
Tribe: Lebiini			
Cymindis platicollis	3.85	5.18	6.83
Tribe: Harpalini			
Dioryche subrecta	--	2.13	--
Tribe: Pterostichini			
Galerita lecontei veracrusis	2.72	--	--
Tribe: Harpalini			
Poecilius versicolor	5.53	8.08	7.59
Stenolophus quinquepustulatus	5.29	6.40	8.34
Subfamily: Scaritinae **Tribe:** Scaritini			
Scarites quadriceps	2.40	3.35	7.96
Scarites subterraneus	1.92	2.59	3.41

Relative abundance

Pheropsophus lissoderus (24.33%) was the most abundant species followed by *Pheropsophus catoirei* (13.17%), *Poecilus Versicolor* (7.19%) and *Pheropsophus africanus* (6.89%) whereas the least relative abundance was recorded for *Galerita lecontei* (0.85%), and *Brachinus bilineatus* (0.77%) (Fig. 1).

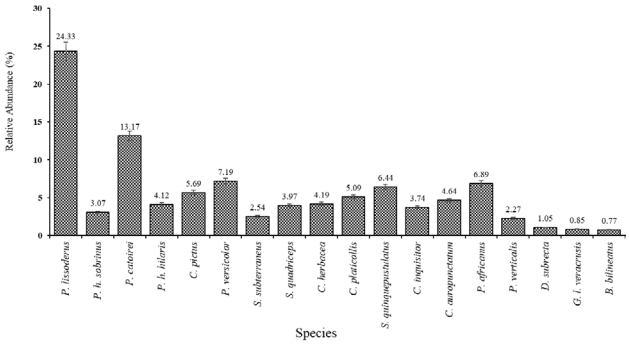

Fig. 1. Overall relative abundance of species at district Mandi Bahauddin from August 2020 to July 2021.

Community diversity

Species richness and the abundance was the highest in Malkwal (16 species and 1969 specimens), followed by Phalia (16 species and 1248 specimens), and *Mandi Bahauddin* (14 species and 791 specimens). The diversity indices show that maximum diversity has been recorded from Phalia (D = 0.125) followed by Malakwal (D = 0.108) and Mandi Bahauddin (D = 0.098). Shannon (H) index points to that the highest richness of ground beetles was present in Malakwal (2.51) followed by Mandi Bahauddin (2.5) and Phalia (2.4). Highest evenness was observed at Mandi Bahauddin (e^H/S = 0.87) followed by Malakwal (e^H/S = 0.77) and Phalia (e^H/S = 0.72). Similar trend in the values of the other indices were observed (Table II).

Table II. Diversity indices calculated for three subdivisions of district Mandi Bahauddin from August 2020 to July 2021.

	Phalia	Malakwal	Mandi Bahauddin	Overall
Taxa_S	16	16	14	18
Individuals	1248	1969	791	4008
Dominance_D	0.125	0.108	0.098	0.107
Simpson_1-D	0.876	0.893	0.902	0.893
Shannon_H	2.433	2.510	2.495	2.545
Evenness_e^H/S	0.712	0.769	0.866	0.709
Brillouin	2.400	2.486	2.449	2.531
Menhinick	0.453	0.361	0.498	0.284
Margalef	2.104	1.978	1.948	2.049
Equitability_J	0.877	0.905	0.945	0.881
Fisher_alpha	2.589	2.381	2.416	2.429
Berger-Parker	0.276	0.235	0.212	0.243

Table III. Main species contributing to dissimilarities among three site communities.

Species	Overall dissimilarity	Mean abundance	Mean abundance	Mean dissimilarity	Contribution	Cumulative
		Phalia	**Malakwal**			
Pheropsophus catoirei	28.88%	162	288	3.917	162	288
P. lissoderus		345	462	3.637	345	462
P. verticalis		0	91	2.829	0	91
Poecilius versicolor		69	159	2.798	69	159
Calasoma inquisitor		30	96	2.052	30	96
Calasoma auropunctatum		48	96	1.492	48	96
Stenoloplius quinquepustulatus		66	126	1.865	66	126
Cymindis platicollis		48	102	1.679	48	102
Dioryche subrecta		0	42	1.306	0	42
Cicindela herbacea		42	84	1.306	42	84
		Phalia	**Mandi Bahauddin**			
Pheropsophus lissoderus	26.53%	345	168	8.681	32.72	32.72
P. catoirei		162	78	4.12	15.53	48.24
P. africanus		100	53	2.305	8.688	70.79
Chlaenius pictus		114	39	3.678	13.86	62.11
G. lecontei veracrusis		34	0	1.667	6.285	77.08
Scarites quadriceps		30	63	1.618	6.1	83.18
Brachinus bilineatus		31	0	1.52	5.73	88.91
P. hilaris sobrinus		45	30	0.7357	2.773	91.68
P. hilaris hilaris		60	45	0.7357	2.773	94.45
Poecilius versicolor		69	60	0.4414	1.664	96.12
		Malakwal	**Mandi Bahauddin**			
P. lissoderus	42.68%	462	168	10.65	24.96	24.96
Pheropsophus catoirei		288	78	7.609	17.83	42.78
Poecilius versicolor		159	60	3.587	8.404	51.19
Pheropsophus verticalis		91	0	3.297	7.725	58.91
Calasoma inquisitor		96	24	2.609	6.112	65.03
Pheropsophus africanus		123	53	2.536	5.942	70.97
S. quinquepustulatus		126	66	2.174	5.093	76.06
Calasoma auropunctatum		96	42	1.957	4.584	80.65
Cymindis platicollis		102	54	1.739	4.075	84.72
Cicindela herbacea		84	42	1.522	3.565	88.29

Community contributions

SIMPER analysis showed that the overall dissimilarity between Phalia and Mandi Bahauddin is (26.53%). *Pheropsophus lissoderus* (8.681 %), *Pheropsophus catoirei* (4.12 %), *Chlaenius pictus* (3.678%), *Pheropsophus africanus* (2.31 %) showed maximum contribution in average dissimilarity between Phalia and Mandi Bahauddin. *Pheropsophus verticalis*, *Stenolophus quinquepustulatus*, *Cicindela herbacea,* and *Dioryche subrecta* showed no contribution in dissimilarity between Phalia and Mandi Bahauddin (Table III).

The overall dissimilarity between Malakwal and Mandi Bahauddin is 42.62%. *Pheropsophus lissoderus* (10.65 %), *Pheropsophus catoirei* (7.60 %), *Poecilius versicolor* (3.58 %), *Pheropsophus verticalis* (3.29 %), *Calasoma inquisitor* (2.60 %), *Pheropsophus africanus* (2.54 %), *Stenolophus quinquepustulatus* (2.17 %) show maximum contribution in dissimilarity between Malakwal

and Mandi Bahauddin. There is no contribution of *Brachinus bilineatus* and *Galerita lecontei veracrusis* in average dissimilarity among Malakwal and Mandi Bahauddin. An overall dissimilarity of 28.88% was observed between Phalia and Malakwal. *Pheropsophus catoirei* (3.92 %), *Pheropsophus lissoderus* (3.64 %), *Pheropsophus verticalis* (2.83 %), *Poecilius versicolor* (2.8 %), *Calasoma inquisitor* (2.05 %) show maximum contribution in dissimilarity between Phalia and Malakwal. On the other hand, *Pheropsophus hilaris hilaris* showed no contribution in dissimilarity between Phalia and Malakwal (Table III).

DISCUSSION

In this study, 4008 carabid beetles belonging to 11 genera and 16 species were collected, which is comparable to the species recorded in Sukkur (05 species) (Soomro *et al*., 2021), Haripur (03 genera and 05 species) (Bibi and Rehman, 2020), and Chakwal (21 species and 11 genera; (Mishkatullah, 2018). We recorded 14 species common in all three subdivisions with Pheropsophus lissoderus was most abundant in all three locations. Phalia and Mandi Bahauddin tehsils have extended suburbs with sugarcane, rice and wheat as major crops.

Pheropsophus lissoderus (24.33%) was the most abundant species followed by *Pheropsophus catoirei* (13.17%) and *Poecilus versicolor* (7.19%). In Malakwal, we observed only five species which were dominant ≥ 5 % abundance as compared to six in Phalia and ten in Mandi Bahauddin. Agroecosystems are expected to harbor decreased number of ground beetles because of their sensitivity habitat modification and agricultural practices (Rischen *et al*., 2022). Ground beetle assemblages have shown associations with broad habitat types (Niemelä *et al*., 1992) and individual ground beetle species affect community structure (Clark *et al*., 1997). Malakwal showed the higher values of indices (Shannon index: 2.51; Brillouin: 2.486) which may be owed to less anthropogenic disturbance (except for agricultural practices) as compared to Phalia and Mandi Bahauddin. Malakwal, Phalia and Mandi Bahauddin being an agricultural lands with dominant vegetation includes citrus fruits, wheat, sugarcane and rice (Hussain *et al*., 2020).

In our study area, habitat type at local scale was either crops or field margins surrounded with tree plantation or interspersed citrus plants in all study sites. This has provided favorable microenvironment for the ubiquitous species to be distributed equally in all three sites. Higher diversity was recorded in the heterogeneous habitat which provides diverse niches and more means for resources utilization as compared to homogenous habitat (Liu *et al*., 2015). However, earlier reported that the isolation from the herbaceous habitats increase carabid species richness and abundance (Uzman *et al*., 2020). Ground beetles have shown non-significant difference in diversity between forest and agricultural fields (Avgın, 2006).

Predatory ground beetles have limited food options in agricultural landscapes, therefore, track resources around field margins. Ground beetles with a predatory life style were found in greater proportion the crop fields as compared to the grasslands (Hanson *et al*., 2016). Phytophagous ground beetles are directly affected by the disruption of agricultural landscapes and vegetation (Bommarco, 1998). All these factors contribute to the lower diversity at Mandi Bahauddin which is characterized by more habitat disruption as compared to Phalia and Malakwal where more land is arable and vegetation cover is dense.

CONCLUSION

In conclusion, our results show that ground beetle assemblages in the district Mandi Bahauddin have relatively greater diversity and abundance compared to number of species and their abundance reported from other districts of Pakistan. These results imply that predator-prey relationship have existed in these croplands which suggested that these generalist predator communities. Our results suggest that ground beetle fauna in Mandi Bahauddin could serve as natural biological control agents. Our study reported *Poecilus versicolor* for the first time from Pakistan.

IBR approval

This study was approved by the Ethical Committee of the University of Gujrat.

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Ethical statement

All efforts were taken to minimize pain and discomfort to the animal while conducting this research according to the ethical protocol of the University of Gujrat.

Statement of conflict of interest

The authors have declared no conflict of interest.

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