Pakistan J. Zool., pp 1-11, 2023. DOI: https://dx.doi.org/10.17582/journal.pjz/20230613020616

Distributional Patterns of Carabid Beetles under Humid Subtropical Climate in Croplands of Sialkot

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Article Information
Received 13 June 2023
Revised 05 September 2023
Accepted 18 September 2023
Available online 28 November 2023 (early access)

Authors' Contribution
MH developed the original hypothesis, designed the experiment, and finalized the manuscript. SL collected the data for this study, conducted the statistical analysis and prepared the draft. MK helped in interpreting the results. KA and SHS proofread the manuscript.

Key words
Ground beetles, Carabidae, *Calosoma*, Croplands, Carabids

ABSTRACT

Pakistan with its diverse climatic and topographical features, is expected to harbor a great diversity of insect species; however, insect fauna of global significance lacks taxonomic and ecological exploration in Pakistan. We explored species diversity and community composition of carabid beetles from croplands. Sampling was conducted fortnightly from August 2020 to July 2021 from district Sialkot i.e., Sialkot, Sambrial, and Pasrur. Specimens were collected by handpicking during the day while pitfall traps were used for nocturnal sampling. Diversity indices and similarities percentage (SIMPER) were calculated for all study sites. We reported 15 species belonging to four subfamilies, six tribes, and eight genera. *Calosoma inquisitor* (15.18%), *Pheropsophus verticalis* (12.37%), and *Pheropsophus darwini* (11.54%) were the most abundant species in district Sialkot. The values of diversity indices calculated for different sites show high species diversity and evenness in Sambrial (D = 0.09, e^H/S = 0.94) followed by Pasrur (D = 0.08, e^H/S = 0.93) and Sialkot (D = 0.11, e^H/S = 0.84). Species richness was highest in Pasrur (H = 2.49) followed by Sambrial (H = 2.42) and Sialkot (H = 2.22). *Galerita bicolor* and *Galerita lecontei veracrucis* were reported as new to Pakistan. The study emphasized that ground beetles are one of the key components of agroecosystems and need to be explored extensively concerning accelerated habitat modification and habitat types.

INTRODUCTION

One of the key global issues is biodiversity loss in response to climate change, land-use practices, pollution, overexploitation, and agricultural intensification resulting in habitat modification, fragmentation, microclimatic variation, and habitat loss (Cardoso *et al*., 2020; Rounsevell *et al*., 2018; van der Meer *et al*., 2020). Climate change and extensive agriculture are key drivers of the global decrease in insect biodiversity (Raven and Wagner, 2021). The rate of species extinction is 1000 times faster compared to the historical trends, mainly due to climate change and associated anethropogenic activities (JM *et al*., 2015). To mitigate biodiversity decline, the conservation, and re-establishment of semi-natural habitats and less intensively managed habitats in agricultural landscapes have been encouraged (Wang *et al*., 2021). Several studies have identified agricultural practices and extension as principal contributing factors to species extinction (Wepprich *et al*., 2019; Forister *et al*., 2016; Raven and Wagner, 2021).

Several studies have been conducted to explore major insect fauna from Pakistan (Hussain and Umar, 2021; Hussain *et al*., 2023; Ramzan *et al*., 2021; Asghar *et al*., 2022; Maryam *et al*., 2020; Ane and Hussain, 2016). Major insect taxa assessed from different habitats and climatic zones during last two decades include butterflies (Roberts, 2001; Khan *et al*., 2014, 2015, 2021; Abbas *et al*., 2002; Bibi *et al*., 2022; Yu-Feng *et al*., 2020; Mangi *et al*., 2023), dung beetles (Siddiqui *et al*., 2014; Noureen *et al*., 2015b; Ghazanfar *et al*., 2017; Nasir *et al*., 2016; Hussain *et al*., 2020, 2022a; Abbas *et al*., 2015; Ali *et al*., 2015; Noureen *et al*., 2015a, 2021), coccinellid beetles (Hussain *et al*., 2018, 2022b; Ahmed *et al*., 2017), grasshoppers (Hussain *et al*., 2017; Ali and Panhwar, 2017), bees and wasps (Bashir *et al*., 2019; Hussain *et al*., 2010, 2012; Bashir *et al*., 2023), and ground beetles (Rafi *et al*., 2017; Rahim *et al*., 2013b; Azadbakhsh and Rafi, 2017; Bibi and Rehman, 2020; Hussain *et al*., 2022c). Coleoptera play an important role in agroecosystems due to their high diversity, abundance,

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0030-9923/2023/0001-0001 $ 9.00/0

wide distribution, and role as biocontrol agents of pests (Manzoor *et al*., 2020; Perveen, 2015; Bashir *et al*., 2023).

Ground beetles (Carabidae) are abundant and species-rich in cultivable areas across the globe with almost 40,000 species (Lövei and Sunderland, 1996). Carabid beetles exhibit various morphological forms and diverse ecological roles i.e., predation, herbivory, and scavenging (Lövei and Sunderland, 1996). Carabid species are sensitive to anthropogenic changes in soil habitats. Thus, they act as bioindicators and are used to characterize habitat disturbance by responding to changes in vegetation height, and supplementary habitats (corridors) for generalist and mesophilous species (Lövei and Sunderland, 1996; Rainio and Niemelä, 2003; Rebrina *et al*., 2022). Moreover, they are important pest-control agents due to their predatory polyphagous diet (Symondson *et al*., 2002; Vichitbandha and Wise, 2002). Carabid communities may serve as an important bio-indicators as well biocontrol agents in agricultural landscapes (Avgın and Luff, 2010; Skłodowski, 2017; Schwerk *et al*., 2020; Soomro *et al*., 2021).

The checklist of ground beetles (Carabidae) presented earlier included 238 species from Pakistan (Kazi *et al*., 2016). Studies on carabid beetles in Pakistan reported five species from Haripur, KPK, Pakistan (Bibi and Rehman, 2020), 38 species from National Insect Museum of Pakistan (Azadbakhsh and Rafi, 2017) 11 species from Mekran division, Baluchistan (Khatri *et al*., 2016), 12 species from Mansehra Division, KPK (Mishkatullah, 2018), five species from Sindh Province (Soomro *et al*., 2021), and six species of ground beetles from Upper Sindh Plains.

Keeping in view the global importance of carabid beetles, we explored the diversity of carabid beetles from Sialkot. The objective of the study is to document the carabid beetles from farmland and seminatural habitats from Sialkot, Punjab, Pakistan. The study would help to assess diversity and the pattern of ground beetles' distribution in croplands of Sialkot.

MATERIALS AND METHODS

Study area

Sialkot (32.3811° N, 74.4995° E) is one of the main districts of the province of Punjab, Pakistan. It is located in the northeast part of the province and is surrounded by Jammu Kashmir on the north, Narowal on the south, Gujranwala on the west, and Gujrat on the northwest side (Noreen *et al*., 2020). It covers an area of 1200 square miles and is 256m above sea level. Besides the Chenab River on the north side of Sialkot, three seasonal streams also flow through the city i.e., Palkhu, Aik, and Beer. The weather of Sialkot is extremely cold during winters while hot and humid during summer. Sialkot is the sub-humid, warm, and sub-tropical monsoon region of Pakistan (Khan, 2019). Winter temperature might fall to −2 °C and the average rainfall of district Sialkot is almost 1000 mm the highest rainfall is observed from July to September (District Sialkot, 2023).

It has great agricultural potential and plays an important role in the agronomic development of Pakistan (Malik *et al*., 2010). Sialkot district is very fertile land rich with flora. There is a variety of natural vegetation growing in different seasons throughout the year. Major plant varieties of this area include *Catharanthus roseus* (Sada bahar), and *Conyza canadensis* (Horseweed), *Cannabis sativa* (Bhang), *Ipomea carnea* (Bush morning glory), *Cucumis melo* (Wild watermelon), *Ricinus communis* (Castor oil), *Cassia fistula* (Golden shower), *Solanum nigrum* (Nightshade), *Datura inoxia* (Thorn apple), *Withania somnifera* (Winter cherry) and *Tribulus terrestris* (Puncture vine) (Arshad *et al*., 2011).

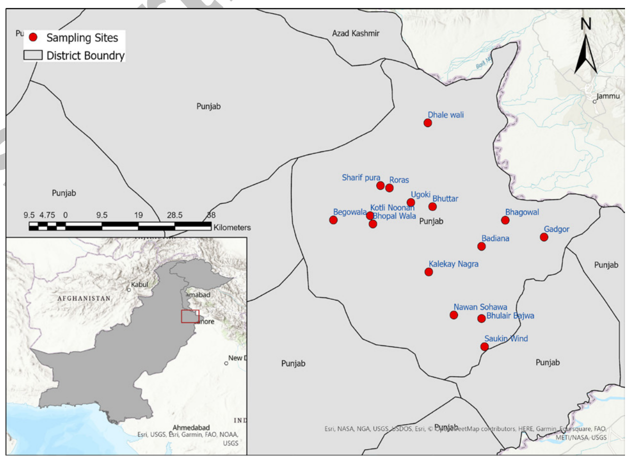

Fig. 1. Map showing study sites in Sialkot, Pasrur, and Sambrial tehsils of district Sialkot.

Sampling procedure

Sampling was carried out fortnightly from randomly selected 15 sites within three tehsils i.e., Pasrur, Sambrial and Sialkot (Fig. 1). Sites were selected based on the vegetation type i.e., croplands and semi-natural habitats. Specimens were collected by handpicking from agricultural fields and seminatural habitats. Pitfall traps were also placed for nocturnal sampling in both type of habitats (Ullah *et al*., 2017). We used disposable plastic cups to prepare the traps with dimensions: diameter (52mm), top diameter (81mm), and height (110 mm). One-third bottom of the trap was filled with vinegar to kill and preserve the specimen. Traps were placed in a 1km transects. Transects were separated by ~100 m. A total of nine traps were placed at each sampling site which were separated by

~150m. The open mouthed traps were surveyed after 24 h and the captured specimens were collected and transferred in labelled plastic containers. For the the reuse of already installed traps, the killing agent was drained and the traps were refilled (Mishkatullah, 2018).

Killing, preservation, and identification

The specimens were identified by by using a microscope (CZM6), labelled and preserved in 70% ethanol (Schauff, 2001; King and Porter, 2004; Post *et al*., 1993). For identification of the specimens, taxonomic keys, field guides and literature were consulted (Abdullah and Azmir, 2021; Choate, 1999, 2001; Ghannem *et al*., 2016; Ribera *et al*., 1999).

Statistical analysis

The simpson and shannon-weiner diversity indices were applied using PAST3 statistical software to calculate species abundance, richness, and evenness across the study area. The similarities percentage (SIMPER) notes the species contributing to dissimilarity among different sites (Simpson, 1949; Shannon, 1949; Clarke and Gorley, 2015; Clarke, 1993; Clarke and Warwick, 1994). Seasonal relative abundance was calculated by arranging data seasonally, i.e. summer (April–October) and winter (November–March) (Hussain *et al*., 2022a).

RESULTS

Overall diversity and abundance

The results indicated that a total of 4558 ground beetle specimens were collected from Sialkot, Pasrur and Sambrial tehsils of district Sialkot from August 2020 to July 2021. The specimens belonged to four subfamilies, six tribes, eight genera, and fifteen species. The maximum number of species was recorded from genus *Pheropsophus* (7 species) followed by genus *Galerita* (2 species, Table I).

Overall relative abundance of species at district Sialkot indicated that *Pheropsophus hilaris sobrinus* (15.18%) was the most abundant species followed by *Pheropsophus hilaris hilaris* (12.37%), and *Pheropsophus lissoderus* (11.54%) (Fig. 2). We also indentified that *Galerita bicolor* and *Galerita lecontei veracrucis* were new to Pakistan and were being reported for the first time from this region.

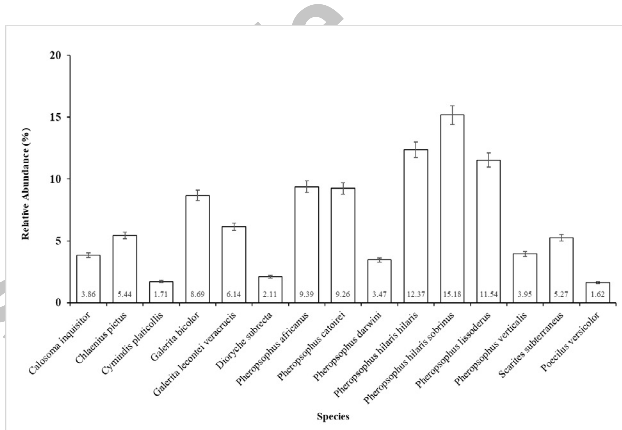

Fig. 2. Overall relative abundance of carabid beetles in District Sialkot.

Table I. Relative abundance (%) of carabid beeles (family Carabidae) in different tehsils of district Sialkot.

Subfamily	Tribe	Genus	Species	Guild	Relative abundance (%)		
					Pasrur	Sialkot	Sambrial
Carabinae	Carabini	*Calosoma*	*Calosoma inquisitor*	Predator	5.81	--	5.23
Harpalinae	Chlaeniini	*Chlaenius*	*Chlaenius pictus*	Predator	8.06	--	7.52
	Lebiini	*Cymindis*	*Cymindis platicollis*	Predator	4.15	0.58	--
	Harpalini	*Dioryche*	*Dioryche subrecta*	Predator	3.08	3.19	--
	Galeritini	*Galerita*	*Galerita bicolor*	Predator	6.75	9.57	10.07
			G. lecontei veracrucis	Predator	5.69	6.96	5.91
	Pterostichini	*Poecilus*	*Poecilus versicolor*	Predator	--	--	4.97
Brachininae	Brachinini	*Pheropso-phus*	*Pheropsophus africanus*	Predator	9.95	11.01	7.25
			P. catoirei	Predator	8.77	10.43	8.72
			P. darwini	Predator	--	4.35	6.58
			P. hilaris hilaris	Predator	13.15	14.49	9.53
			P. hilaris sobrinus	Predator	11.97	17.83	16.38
			P. lissoderus	Predator	9.83	13.77	11.41
			P. verticalis	Predator	4.98	--	6.44
Scaritinae	Scaritini	*Scarites*	*Scarites subterraneus*	Predator	7.82	7.83	--

Table II. Diversity indices calculated for different sites from August 2020 to July 2021.

	Sialkot	Sambrial	Pasrur	Overall
Taxa_S	11	12	13	15
Individuals	1380	1490	1688	4558
Dominance_D	0.1178	0.09474	0.0878	0.09137
Simpson_1-D	0.8822	0.9053	0.9122	0.9086
Shannon_H	2.224	2.423	2.493	2.521
Evenness_e^H/S	0.8408	0.94	0.9306	0.8295
Brillouin	2.202	2.399	2.47	2.51
Menhinick	0.2961	0.3109	0.3164	0.2222
Margalef	1.383	1.506	1.615	1.662
Equitability_J	0.928	0.975	0.972	0.931
Fisher_alpha	1.632	1.783	1.917	1.931
Berger-Parker	0.1783	0.1638	0.1315	0.1518

Pheropsophus hilaris sobrinus (17.83%) showed the highest relative abundance at tehsil Sialkot, followed by *Pheropsophus hilaris hilaris* (14.49%) and *Pheropsophus lissoderus* (13.77%). The lowest relative abundance was recorded for *Cymindis platicollis* (0.58%). At tehsil Sambrial, the highest relative abundance was recorded for *Pheropsophus hilaris sobrinus* (16.38%) followed by *Pheropsophus lissoderus* (11.41%) and *Galerita bicolor* (10.07%). *Poecilus versicolor* (4.97%) showed the lowest relative abundance from tehsil Sambrial. At tehsil Pasrur, *Pheropsophus hilaris hilaris* (13.15%) showed the highest relative abundance followed by *Pheropsophus hilaris sobrinus* (11.97%) and *Pheropsophus africanus* (9.95%). The lowest relative abundance was recorded for *Cymindis platicollis* (4.15%) and *Dioryche subrecta* (3.08%) (Table I).

Diversity indices

The values of species dominanace (1-D) showed variations in the the diversity of species at a given site (value closer to 0 indicates less diversity while 1 indicates high diversity (Table II). The Simpson's index (1-D) shows that species are more diverse in Pasrur (1-D = 0.91) followed by Sambrial (1-D = 0.90) and Sialkot (1-D = 0.88). Similarly, Shannon index (H) indicate high species richness in Pasrur (H = 2.49) followed by Sambrial (H = 2.42) and Sialkot (H = 2.2). The evenness value (e^H/S) indicated closer to 1 showed high evenness while a 0 value shows low evenness i.e., Sambrial (e^H/S = 0.94) followed by Pasrur (e^H/S = 0.93) and Sialkot (e^H/S = 0.84). The equitability value (J) indicated that the species are almost equally distributed in Sambrial (J = 0.975) and Pasrur (J = 0.972) whereas in Sialkot (J = 0.927), species are less equally distributed as compared to Sambrial and Pasrur (Table II). Margalef index explains the impact of sample size on the soecies richness i.e., the higher the index the greater the richness. Pasrur (1.615) exhibited higher richness as compared to sambrial (1.506) and Sialkot (1.383).

Table III. Relative abundance (%) of carabid beetles from study sites during summer and winter. Each value (%) calculated from total abundance at each site during seasons.

Species	Sialkot		Sambrial		Pasrur	
	Winter	Summer	Winter	Summer	Winter	Summer
Pheropsophus africanus	21.62	17.15	14.41	16.72	13.85	12.45
Galerita lecontei veracrucis	18.92	9.29	4.50	9.46	10.77	9.37
Cymindis platicollis	17.57	13.94	8.11	9.78	16.15	13.57
Dioryche subrecta	14.86	10.42	4.50	7.73	13.85	10.21
Pheropsophus lissoderus	14.86	13.46	8.11	11.99	9.23	10.49
Galerita bicolor	5.41	--	--	--	3.08	4.34
Pheropsophus verticalis	2.70	8.01	1.80	6.62	3.08	6.57
Pheropsophus catoirei	2.70	8.33	--	--	4.62	8.67
Poecilus versicolor	1.35	4.01	--	--	--	3.64
Calosoma inquisitor	--	--	33.33	0.32	--	0.42
Chlaenius pictus	--	--	9.01	7.26	12.31	7.97
Pheropsophus darwini	--	10.58	5.41	10.88	6.92	7.55
Scarites subterraneus	--	4.81	0.90	7.57	--	--
Pheropsophus hilaris hilaris	--	--	5.41	6.62	6.15	4.76
Pheropsophus hilaris sobrinus	--	--	4.50	5.05	--	--

Table IV. SIMPER results including species contributing to dissimilarities among sites.

Species	Overall dissimilarity	Mean dissimilarity	Contribution %	Cumulative %	Mean abundance (No.)	
					Sialkot	Sambrial
Chlaenius pictus	25.16 %	4.46	18.33	18.33	--	10.60
Scarites subterraneus		4.34	18.00	36.33	10.4	--
Pheropsophus verticalis		4.18	16.97	53.3	--	09.80
Poecilus versicolor		3.59	14.90	68.2	--	08.60
Dioryche subrecta		2.77	11.49	79.69	6.63	--
Cymindis platicollis		1.18	04.89	84.59	2.83	--
Pheropsophus hilaris hilaris		0.93	03.87	88.44	14.1	11.90
Pheropsophus darwini		0.90	03.73	92.17	7.75	09.90
Pheropsophus africanus		0.81	03.36	95.53	12.3	10.40
Galerita bicolor		0.32	01.32	96.84	11.5	12.20
Pheropsophus lissoderus		0.32	01.30	98.13	13.8	13.00
Pheropsophus catoirei		0.25	01.04	99.17	12.0	11.40
Pheropsophus lecontei veracrucis		0.18	0.72	99.89	9.80	09.38
Pheropsophus hilaris sobrinus		0.03	0.11	100	15.70	15.60
Chlaenius pictus	16.06 %	04.62	28.78	28.78	--	11.7
Pheropsophus verticalis		03.63	22.62	51.39	--	9.16
Pheropsophus darwini		03.07	19.11	70.51	7.75	--
Cymindis platicollis		02.19	13.67	84.17	2.83	8.37
Pheropsophus hilaris sobrinus		0.583	03.63	87.80	15.7	14.2
Scarites subterraneus		0.434	02.71	90.51	10.4	11.5
Pheropsophus lissoderus		0.356	02.22	92.73	13.8	12.9
Galerita bicolor		0.321	02.01	94.73	11.5	10.7
Pheropsophus hilaris hilaris		0.301	01.87	96.6	14.1	14.9
Pheropsophus africanus		0.251	1.56	98.16	12.3	13.0
Dioryche subrecta		0.230	1.43	99.59	6.63	7.21
Pheropsophus catoirei		0.06579	0.4096	100	12	12.2
Poecilus versicolor		0	0	100	0	0
Galerita lecontei veracrucis		0	0	100	9.8	9.8
					Sambrial	**Pasrur**
Scarites subterraneus	22.12 %	4.447	20.10	20.10	--	11.5
Pheropsophus darwini		3.831	17.32	37.43	9.90	--
Poecilus versicolor		3.329	15.05	52.48	8.60	--
Cymindis platicollis		3.238	14.64	67.12	--	8.37
Dioryche subrecta		2.791	12.62	79.74	--	7.21
Pheropsophus hilaris hilaris		1.155	5.222	84.96	11.9	14.9
Pheropsophus africanus		0.9943	4.496	89.46	10.4	13.0
Galerita bicolor		0.6077	2.747	92.21	12.2	10.7
Pheropsophus hilaris sobrinus		0.5446	2.462	94.67	15.6	14.2
Chlaenius pictus		0.4176	1.888	96.56	10.6	11.7
Pheropsophus catoirei		0.2957	1.337	97.89	11.4	12.2
Pheropsophus verticalis		0.245	1.108	99.00	09.8	9.16
Galerita lecontei veracrucis		0.1614	0.7297	99.73	9.38	9.80
Pheropsophus lissoderus		0.0596	0.2695	100	13.0	12.9

Species contributing to dissimilarity among different sites

SIMPER results for the species contributing to dissimilarity among different sites in district Sialkot. Overall dissimilarity among Sialkot and Sambrial is 25.16%. Top species contributing to dissimilarity include *Chlaenius pictus* (18.33%), *Scarites subterraneus* (18%), and *Pheropsophus verticalis* (16.97%) whereas *Pheropsophus hilaris sobrinus* (0.11%) has the least contribution to dissimilarity among the species. Sialkot and Pasrur showed 16.06% dissimilarity in species distribution. *Chlaenius pictus* (28.78%) and *Pheropsophus verticalis* (22.62%) have the highest contribution to dissimilarity whereas, *Poecilus versicolor* and *Galerita lecontei veracrucis* have no contribution to dissimilarity (Table IV).

Similarly, Sambrial and Pasrur have 22.12% overall dissimilarity among the species. The top species contributing to dissimilarity include *Scarites subterraneus* (20.1%) and *Pheropsophus darwini* (17.32%) whereas, *Galerita lecontei veracrucis* (0.72%) and *Pheropsophus lissoderus* (0.26%) have the least contribution to dissimilarity among the species at Sambrial and Pasrur.

Rank abundance curve

Rank abundance curve reflects evenness in the slope of the line. Whereas a steep gradient represents low evenness, while a shallow gradient is indicative of higher species evenness. The rank abundance graph of species in three study sites showed a shallow gradient of Pasrur and Sambrial which indicated evenness in the distribution of species whereas the steep curve of Sialkot indicates low evenness in species abundance (Fig. 3). Pasrur and Sambrial were equally dominant sites as compared tehsil Sialkot. Dominant species included *Pheropsophus africanus, Galerita lecontei veracrucis, Cymindis platicollis, Dioryche subrecta* and *Pheropsophus lissoderus* (Table III).

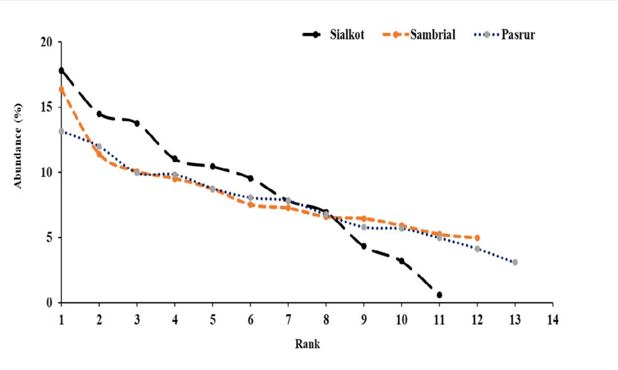

Fig. 3. Rank abundance graph of species in three tehsils (Sialkot, Sambrial, and Pasrur).

DISCUSSION

Ground beetles (family Carabidae) belong to a large family of predatory ground-dwelling beetles. The studies on carabid beetles report their dependence on biotic and abiotic features of their local habitats (Pizzolotto *et al*., 2018; Heino *et al*., 2019). Carabid community rely on vegetation characteristics mainly through local effects (Schaffers *et al*., 2008; Worthen and Merriman, 2013). Microclimatic conditions like food sources, temperature, moisture and sunlight influence carabid assemblages (Luff, 1980; Ernsting and Isaaks, 2000). In our study, we recorded 15 species of carabid beetles that belonged to the carnivorous guild from agricultural landscapes. Our study sites represent similarities in microclimatic conditions (temperature, light, and biotic communities), however local differences in vegetation and other features in three tehsils (Sialkot, Pasrur and Sambrial) were observed which have influenced species richness and abundance.

Ground beetle assemblages have been reported amongst important insect communities from the agricultural landscapes across the globe (Szyszko-Podgórska *et al*., 2021; Rainio and Niemelä, 2003). Interestingly, most species of carabids were observed with reasonably higher magnitudes from all three study sites except *Scarites subterraneus* (from Sambrial), *Pheropsophus darwini* (from Pasrur), *Cymindis platicollis* (from Sambrial) and *Dioryche subrecta* (from Sambrial). *Poecilus versicolor* was not recorded from Sialkot and Pasrur. *Calosoma inquisitor*, *Chlaenius pictus*, *Pheropsophus verticalis* and *Poecilus versicolor* (also from Pasrur) were not recorded from Sialkot. Additionally, these results of ground beetle assemblages recorded from district Sialkot indicated slight variations in the species abundance, richness, and distribution across the sites i.e., Sialkot, Sambrial, and Pasrur.

Vegetation types and higher altitude and lower temperature ranges influence species diversity. Such results of lower diversity (only five species: *Carabus caschmirensis, Chlaenius quadricolar, Pheropsophus sobrinus, Chlaenius laticollis* and *Chlaenius hamifer*) were reported earlier from District Poonch, Azad Kashmir (Rahim *et al*., 2013a). Surprisingly lower diversity of species and abundance of ground beetles (Coleoptera: Carabidae) from Upper Sindh Plains. Only six species were reported: *Calosoma auropunctuatumm, Calsoma sycophantum, Harpalus erythropus, Harpalus suensoni, Mecyclothorax cordicolis* and *Nesamblyops oreobius*. Fourteen species of Brachinini tribe have been reported from northern Pakistan (Ullah *et al*., 2017). Variations in the topography, altitudes, climatic conditions, and vegetation type determine carabid community composition.

SIMPER results highlighted that Sialkot-Sambrial comparison indicated 25.16 % contribution in the dissimilarity of species abundance. In Sialkot-Pasrur, 16.06% average dissimilarity was observed. Main species contributing *Chlaenius pictus* (18.33 % in Sialkot-Sambrial, 28.78% in Sialkot-Pasrur) and *Scarites subterraneus* (20.10 % in Sambrial-Pasrur). The distribution patterns of *Chlaenius pictus* in agricultural landscapes indicated variations in the abundance in response to vegetation, temperature, and microenvironment (Satpathi, 2021; Knapp *et al*., 2019).

Twelve species were reported from coastal areas of Sindh with most abundant species include *Calosoma aurapunctuatum, Calosoma scyophantum* and *Anthia sexuamatta*. The species belonging to the genus *Pheropsophus* were found to be the most abundant in Sialkot. Species were found to be evenly distributed in Sambrial and Pasrur (less anthropogenic activities) as compared to Sialkot (more anthropogenic activities). Similar results have been reported for changes in the composition and abundance of carabid species due to the disturbance caused by anthropogenic activities (Rainio and Niemelä, 2003). Habitat fragmentation, vegetation, and soil water content are the major factors affecting the distribution and abundance of carabid beetles (Wei *et al*., 2020; Kazi *et al*., 2016). The values of diversity indices show high species diversity and evenness in Sambrial followed by Pasrur and Sialkot. Species richness was highest in Pasrur followed by Sambrial and Sialkot. The seasonal diversity of carabid beetles has also been reported similar to our findings from Sindh, Pakistan (Sahito *et al*., 2020).

CONCLUSION

Carabid beetle assemblages indicated dominance of predatory species in croplands of Sialkot. Among 15 species recorded, *Galerita bicolor* and *Galerita lecontei veracrucis* were reported as new to Pakistan. Our study described Pheropsophus as the most abundant genus with seven species out of total fifteen species belong to this genus. Variations in the number of species from three tehsils indicated local differences in the microclimatic conditions in the sites.

ACKNOWLEDGEMENT

Authors are grateful to the Head of Laboratory of Systematics and Pest Management, Department of Zoology-UOG, for providing all the resources and feasible environment for conducting the research work.

Funding

The study received no external funding.

IRB approval

The study was approved by the Ethical Committee of the University of Gujrat, Gujrat.

Ethical statement

All efforts were made to minimize pain and discomfort to the specimens during research.

Statement of conflict of interest

The authors have declared no conflict of interest.

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