Research Article

Diversity and Distributional Patterns of Grasshoppers in Croplands of District Gujrat, Punjab, Pakistan

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Abstract | Grasshoppers are major herbivores that occupy agricultural landscapes across the globe due to their ecological, behavioural, and taxonomic diversification. The periodic assessment of the population of grasshoppers in field crops is crucial in devising and implementing pest management strategies. This study explored croplands to document the diversity of grasshoppers from selected locales of district Gujrat. Sampling was conducted on sunny bright days between 11 am to 4 pm by using a sweep net. Data was collected fortnightly from 2015 to 2016. We collected 1266 specimens representing 19 species which belonged to two suborders, three families, nine subfamilies, 12 tribes, and 15 genera. Acrididae (933 specimens; 15 species) was the most abundant family followed by Tettigonidae (1197 specimens; three species) and Pyrgomorphidae (136 specimens; one species). Maximum relative abundance was shown by *Oxya hyla hyla* (12.80 %) followed by *Acrida turrita* (12.72 %), *Atractomorpha crenulata* (10.74 %), *Tettigonia viridissimia* (9.79 %) and *Phlaeoba panteli* (9.72 %). Species richness showed non-significant variations in the study sites. Jamal Pur Saydan was the only site which showed maximum species richness with 19 species and 102 specimens. Whereas seven sites out of 14 showed the presence of 18 species. About 56 % of the contribution in the relative abundance was owed to four species belonging to the suborder Caelifera and one species to the suborder Ensifera. Acrididae (73.70 %) was the largest family that contributed maximum in species abundance followed by Tettigonidae (15.56%), and Pyrgomorphidae (10.74 %). The values of Shannon-wiener index (2.48-2.71) and evenness (0.71-0.84) showed all sites have relatively higher diversity. More explorative studies associated with specific crops and damage assessment need to be conducted for pest management and conservation of biodiversity.

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Introduction

The Gujrat (32.6367° N, 74.1674° E) is a primitive district of Pakistan situated between two rivers, the Jhelum and the Chenab and is bounded by sub-mountainous Bhimber district in the northeast (Ghazanfar *et al.*, 2017; Umar *et al.*, 2022), the Chenab River in the southeast (Hussain *et al.*, 2020)

and the Jhelum River in the northwest (Hussain *et al.*, 2022; Noureen *et al.*, 2015). It has a hot semi-arid climate (BSh), which may also be referred to as a monsoon-influenced humid subtropical climate (Cwa). Major crops grown in the district Gujrat include wheat, rice, millets, maize, sugarcane, pulses and oil seed crops (Hussain *et al.*, 2018). These topographical features, environmental conditions and cropping patterns of the Gujrat district are expected to make species diversified, especially insects (Hussain *et al.*, 2010; Noureen *et al.*, 2015).

Order Orthoptera (class: Insecta) includes diversified groups of insects representing around 22,500 species which are distributed globally (Mustafa *et al.*, 2024). Grasshoppers play a pivotal role in rolling the biodiversity of grassland areas and deciduous woods (Guo *et al.*, 2006) and sometimes, grasshoppers become a keystone species temporarily (Dhakad *et al.*, 2014). Grasshoppers are occupants of almost all terrestrial landscapes i.e., agroecosystems, agroforestry, rangelands, etc., (Culliney, 2013). These are significantly herbivorous, assemble as swarms and act as important links in food chains (Zhu *et al.*, 2020). A study claims that 1750 species of grasshoppers have been reported from India (Jana *et al.*, 2015; Tandon and Hazra, 1998). Various studies have reported grasshopper species from different districts of Pakistan highlighting their diversity and distribution patterns. Perusal of literature indicated species diversity during different surveys i.e., Mirpur (Tamkeen *et al.*, 2011), Karak (Usman *et al.*, 2017), Havelian, Khairpur (Panhwar *et al.*, 2024a), Sialkot (Hussain *et al.*, 2017), Baltistan (Mahmood *et al.*, 2004), Poonch (Nazir *et al.*, 2014), Cholistan (Younus, 2024), and different parts of Sindh (Afghan *et al.*, 2016; Mustafa *et al.*, 2024; Panhwar *et al.*, 2024b; Prince *et al.*, 2022; Sanam *et al.*, 2023; Soomro *et al.*, 2015; Soomro and Sultana, 2023; Sultana *et al.*, 2013, 2024).

Agricultural practices and anthropogenic activities modify and disturb habitat which influences modifications in habitat preference, shifts in distribution patterns and changes in biodiversity. These ecological paradigms related to grasshopper fauna demand for the periodic assessment of diversity for conservation and pest management perspective. Therefore, this study was planned to document distributional patterns of diversity from district Gujrat. This study provided the current status of diversity and population dynamics of grasshoppers.

Materials and Methods

Study area

The sampling sites comprised of selected locales district Gujrat, Pakistan (Figure 1). The data was collected from Jamal Pur Syedan (32.603° N and 74.103° E), Madina Syedan (32.608° N and 74.090° E), Moiun Din Pur (32.583° N and 74.107° E), Beowali (32.599° N and 74.130° E), Chak Kala (32.609° N and 74.149° E), Sook Kalan (32.592° N and 74.148° E), Mrarpur (32.633° N and 74.115° E), Chak Bhola (32.600° N and 74.116° E), Hunjra (32.625° N and 74.137° E), Purba (32.610° N and 74.123° E), Hardaspur (32.641° N and 74.154° E), Tibbi (32.612° N and 74.136° E), Chak Manju (32.615° N and 74.148° E), Piara (32.64° N and 74.103° E), and Bhalar (32.611° N and 74.117° E).

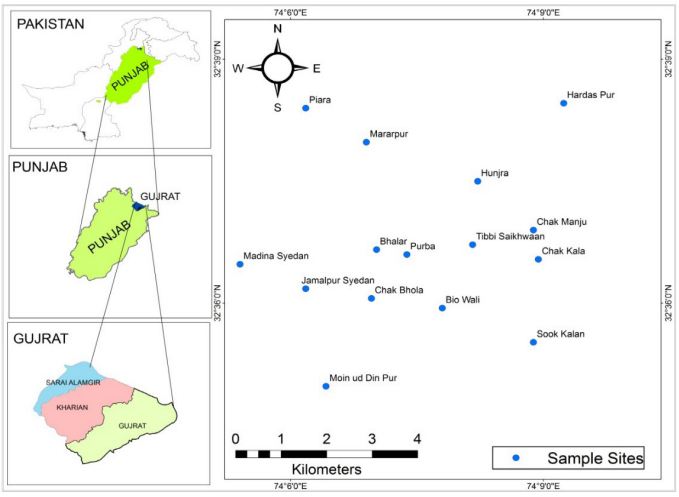

Figure 1: *Map of study sites located in the district Gujrat, Punjab, Pakistan.*

Sampling procedure

Data collection was performed fortnightly by using a sweep net between 11 am to 4 pm from March 2015 to February 2016 on sunny bright days to maximize the chances of detecting different species (Zhang *et al.*, 2024).

Killing, identification and preservation of specimens

Grasshoppers were killed in ethyl alcohol, relaxed, stretched, pinned and left for 72 hrs to dry in the air (Akhtar and Usmani, 2014). The specimens were examined under the Microscope (CZM 6) for identification using the taxonomic keys and published literature (Akhtar *et al.*, 2014; Pfadt, 2002; Smith *et al.*, 2004).

Statistical analysis

The relative abundance of each species was calculated for all sites and seasons. Abundance of species was arranged seasonally i.e., spring (March, April and May), summer (June, July and August), autumn (September, October and November), and winter (December, January and February) (Bashir *et al.*, 2023). Species richness, evenness, and dominance as quantitative measures of biodiversity were calculated for statistical reflection of diversity. Diversity indices including Simpson's index (Simpson, 1949), Shannon-weaver index (Shannon and Weaver, 1949), Berger- Parker dominance index (Berger and Parker, 1970), and Margalef's species richness (Margalef, 1958) were calculated by using PAST software.

Results and Discussion

Species richness

The current study investigated the diversity and abundance of grasshoppers (Orthoptera) across 15 sites in the district Gujrat, Pakistan during four seasons (autumn, spring, and summer, winter). A total of 1266 specimens were collected, and identified as 19 species representing two suborders, three families, nine subfamilies, 12 tribes, and 15 genera (Table 1).

Species composition and relative abundance

Acrididae was the dominant family across all sites and seasons representing about 79 % of the species with 73.70 % of the total abundance. *Oxya hyla hyla* (12.80 %) was the most abundant species followed by *Acrida turrita* (12.72%), *Atractomorpha crenulata* (10.74 %), *Tettigonia viridissimia* (9.79%) and *Phlaeoba panteli* (9.72%) of total collection (Table 1).

Distribution of species

Species composition varied across locations. For example, ten species were observed in all 15 sites whereas *Acrida gigantea, Oxya japonica japonica,* and *Neoconocephalus triops* were recorded from 14 sites. *Melanoplus bivittatus* was not recorded from seven sites, *Camnula pellucida* from four sites and *Ducetia japonica* from three sites (Table 2).

Seasonal abundance

Seasonal variations in species abundance were also observed. In autumn, 19 species were documented with the maximum abundance of *Acrida turrita* (15.25%), followed by *Oxya hyla hyla* (12.40%), *Atractomorpha crenulata* (11.11%), and *Dittopternis venusta* (8.01%).

Table 1: *Overall abundance of grasshopper species from Gujrat, Punjab, Pakistan during 2015-2016.*

Sub order	Family	Subfamily	Tribe	Species	Abundance (no.)	Relative abundance %
Caelifera	Acrididae	Acridinae	Acridini	*Acrida exaltata* (Walker, 1859)	24	1.90
				Acrida gigantea (Herbst, 1786)	58	4.58
				Acrida turrita (Linnaeus, 1758)	161	12.72
				Acrida ungarica (Herbst, 1786)	57	4.50
			Cyrtacanthacridini	*Phlaeoba panteli* (Bolívar, 1902)	123	9.72
			Locustini	*Dittopternis venusta* (Walker, 1870)	78	6.16
		Cyrtacanth-acridinae	Cyrtacanthacridini	*Crytacanthacris tatarica* (Linnaeus, 1758)	50	3.95
		Melanopplinae	Melanoplini	*Melanoplus bivittatus* (Say, 1825)	20	1.58
		Oedipodinae	Hippiscini	*Camnula pellucida* (Scudder, 1863)	20	1.58
			Chortophagini	*Chortophaga viridifasciata* (De Geer, 1773)	48	3.79
			Locustini	*Oedaleus abruptus* (Thunberg, 1815)	28	2.21
			Trilophidiini	*Trilophidia annulata* (Thunberg, 1815)	38	3.00
		Oxyinae	Oxyini	*Hieroglyphus banian* (Fabricius, 1798)	20	1.58
				Oxya hyla hyla (Serville, 1831)	162	12.80
				Oxya japonica japonica (Thunberg, 1824)	46	3.63
	Pyrgo-morphidae	Pyrgomorphinae	Atractomorphini	*Atractomorpha crenulata* (Fabricius, 1793)	136	10.74
Ensifera	Tettigo-niidae	Conocephalinae	Copiphorini	*Neoconocephalus triops* (Linnaeus, 1758)	40	3.16
		Phaneropterinae	Ducetiini	*Ducetia japonica* (Thunberg, 1815)	33	2.61
		Tettigoniinae	Tettigoniini	*Tettigonia viridissimia* (Linnaeus, 1758)	124	9.79

Table 2: *Occurrence of species at different locations in the study area during 2015-2016.*

Species	JPS	MS	MDP	Beowali	CK	SK	Mrarpur	CB	Hunjra	Purba	Hardaspur	Tibbi	CM	Piara	Bhalar
Acrida exaltata	✓	X	✓	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	X	✓
Acrida gigantea	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Acrida turrita	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Acrida ungarica	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Atractomorpha crenulata	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Camnula pellucida	✓	X	✓	✓	X	✓	✓	X	✓	✓	✓	✓	✓	✓	X
Chortophaga viridifasciata	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Crytacanthacris tatarica	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Dittopternis venusta	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ducetia Japonica	✓	✓	✓	✓	✓	✓	✓	✓	X	✓	X	✓	✓	X	✓
Hieroglyphus banian	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Melanoplus bivittatus	✓	✓	X	✓	X	✓	✓	✓	X	✓	X	X	X	✓	✓
Neoconocephalus triops	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Oedaleus abruptus	✓	✓	X	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	✓	✓
Oxya hyla hyla	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Oxya japonica japonica	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	✓
Phlaeoba panteli	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Tettigonia viridissimia	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Trilophidia annulata	✓	✓	X	✓	✓	✓	✓	✓	✓	✓	X	✓	✓	✓	✓

JPS, Jamal Pur Saydan; MS, Madina Saydan; MDP, Moiun Din Pur; CK, Chak Kala; SK, Sook Kalan; CB, Chak Bhola; CM, Chak Manju.

In summer, *Acrida turrita* (13.22%), followed by *Oxya hyla hyla* (11.57%), *Dittopternis venusta* (8.54%) and *Atractomorpha crenulata* (8.26%). Maximum relative abundance of grasshoppers in spring was demonstrated by *Acrida turrita* (10.49%), followed by *Oxya hyla hyla* (8.74%), and *Dittopternis venusta* (5.59%). In winter, only six species were observed out of which *Tettigonia viridissimia, Oxya hyla hyla* and *Phlaeoba panteli* have shown greater abundance (Table 3).

Diversity indices

Diversity indices were calculated to assess the grasshopper diversity across different locations within the study area (Table 4). Simpson's index, Shannon-Wiener index (H), and Fisher's alpha values showed a narrow range of variations in various parameters of diversity such as dominance, richness, and evenness of species. Variations in diversity, with the highest values observed in Chak Bhola (Shannon-Wiener H = 2.71) and Chak Manju (Fisher's alpha = 8.24). Overall, diversity indices indicated a moderately diverse grasshopper population across the study area. The highest value for Menhinick (2.15) was observed in Beowali, Margalef (4.07) in Mrarpur and Equitability (0.94) in Sook Kalan, and Chak Bhola. These indices collectively suggest that the study sites have evenly distributed species with a higher diversity of grasshoppers in the area.

The distribution of grasshopper species is greatly influenced by seasonal changes in the environment and vegetation (Nair, 2007). For example, in tropical areas like Pakistan, multiple generations of many grasshopper species per year are observed adding to greater seasonal diversity (Hussain *et al.*, 2017). Temperature and precipitation, as key environmental variables, contribute significantly in the population dynamics of insects during different seasons (Hussain *et al.*, 2017). The patterns of seasonal distribution of species indicated a shift in the diversity and population abundance of grasshoppers which further expands as the season progresses (Buckley *et al.*, 2021). Research indicates that warmer temperatures can lead to earlier hatching times and increased survival rates of insect species, particularly in arid environments (Bashir *et al.*, 2023; Ghazanfar *et al.*, 2017; Hussain *et al.*, 2018).

Family Acrididae was the dominant species in many studies conducted in different ecological regions of Pakistan though the numbers varied with sites and seasons. For example, the dominance of the Acrididae

Table 3: *Species abundance was calculated seasonally for each species in a given season of during 2015-2016.*

Species	Autumn		Spring		Summer		Winter	
	No.	%	No.	%	No.	%	No.	%
Acrida exaltata (Wa1ker,1859)	05	1.29	7	2.45	12	3.31	--	--
Acrida gigantea (Herbst, 1794)	11	2.84	21	7.34	07	1.93	19	8.26
Acrida turrita (Linnaeus, 1758)	59	15.25	30	10.49	48	13.22	24	10.43
Acrida ungarica (Herbst, 1786)	26	6.72	11	3.85	20	5.51	--	--
Atractomorpha crenulata (Fabricius, 1793)	43	11.11	30	10.49	30	8.26	33	14.35
Camnula pellucida (Scudder, 1862)	05	1.29	07	2.45	08	2.20	--	--
Chortophaga viridifasciata (De Geer, 1773)	13	3.36	19	6.64	16	4.41	--	--
Crytacanthacris tatarica (Linnaeus, 1758)	19	4.91	14	4.90	17	4.68	--	--
Dittopternis venusta (Walker, 1870)	31	8.01	16	5.59	31	8.54	--	--
Ducetia japonica (Thunberg, 1815)	12	3.10	10	3.50	11	3.03	--	--
Hieroglyphus banian (Fabricius, 1798)	04	1.03	06	2.10	10	2.75	--	--
Melanoplus bivittatus (Say, 1825)	06	1.55	05	1.75	09	2.48	--	--
Neoconocephalus triops (Linnaeus 1758)	26	6.72	07	2.45	07	1.93	--	--
Oedaleus abruptus (Thunberg, 1815)	09	2.33	07	2.45	12	3.31	--	--
Oxya hyla hyla (Serville, 1831)	48	12.40	25	8.74	42	11.57	47	20.43
Oxya japonica japonica (Thunberg, 1824)	12	3.10	15	5.24	19	5.23	--	--
Phlaeoba panteli (Bolivar, 1902)	29	7.49	25	8.74	23	6.34	46	20.00
Tettigonia viridissimia (Linnaeus, 1758)	20	5.17	17	5.94	26	7.16	61	26.52
Trilophidia annulata (Thunberg, 1815)	09	2.33	14	4.90	15	4.13	--	--

Table 4: *Various indices showing species richness, evenness, and dominance at different sites during 2015-2016.*

	JPS	MS	MDP	Beow-ali	CK	SK	Mrar-pur	CB	Hunjra	Purba	Har-daspur	Tibbi	CM	Piara	Bhalar
Taxa_S	19	16	16	18	17	17	18	18	17	19	16	18	18	16	18
Individuals	102	99	74	70	78	69	65	87	94	82	91	90	88	84	93
Dominance_D	0.092	0.10	0.10	0.08	0.10	0.08	0.08	0.08	0.09	0.08	0.10	0.08	0.08	0.09	0.08
Simpson_1-D	0.908	0.90	0.90	0.92	0.90	0.92	0.92	0.92	0.91	0.92	0.90	0.92	0.92	0.91	0.92
Shannon_H	2.626	2.50	2.48	2.67	2.49	2.66	2.66	2.71	2.54	2.69	2.50	2.66	2.67	2.55	2.68
Evenness_e^H/S	0.727	0.76	0.74	0.80	0.71	0.84	0.80	0.83	0.79	0.81	0.76	0.79	0.80	0.80	0.81
Brillouin	2.356	2.26	2.18	2.32	2.20	2.32	2.30	2.41	2.29	2.37	2.24	2.37	2.37	2.28	2.40
Menhinick	1.881	1.61	1.86	2.15	1.93	2.05	2.23	1.93	1.65	1.99	1.68	1.90	1.92	1.75	1.87
Margalef	3.892	3.26	3.49	4.00	3.67	3.78	4.07	3.81	3.30	3.86	3.33	3.78	3.80	3.39	3.75
Equitability_J	0.892	0.90	0.89	0.92	0.88	0.94	0.92	0.94	0.92	0.93	0.90	0.92	0.92	0.92	0.93
Fisher_alpha	6.880	5.40	6.28	7.84	6.70	7.21	8.24	6.89	5.54	7.12	5.63	6.77	6.85	5.86	6.65
Berger-Parker	0.177	0.16	0.19	0.17	0.18	0.14	0.15	0.17	0.16	0.16	0.16	0.14	0.15	0.14	0.15
Chao-1	19.20	16	16.6	18.14	17.43	17	19	18	16	18	16	18	18	16	18

JPS, Jamal Pur Saydan; MS, Madina Saydan; MDP, Moiun Din Pur; CK, Chak Kala; SK, Sook Kalan; CB, Chak Bhola; CM, Chak Manju.

in the grasshopper populations has been reported from different landscapes and regions of Pakistan including Ratodero in Sindh (Mustafa *et al.*, 2024), Sialkot (Hussain *et al.*, 2017), Mirpur (Tamkeen *et al.*, 2011), Baltistan (Mahmood *et al.*, 2004), Naushahro Feroze (Shah and Sultana, 2024), Mardan (Saeed *et al.*, 2021), and Sindh (Larik *et al.*, 2021). The diversity of Acridid grasshoppers is associated with vegetation type. For instance, in Sialkot, many grasshopper species were associated with rice crops (Hussain *et al.*, 2017).

In our study, variations in the number of species were observed among 15 sites. For example, maximum

species were recorded from JMS and Purba were inhabited by all 19 species whereas 18 species were recorded from six sites. These variations in the number of species and individuals at different sites may be the result of local differences in crops and level of anthropogenic activities (Hussain *et al.*, 2018, 2022).

The abundance of different Acridid species fluctuates from season to season (Riffat *et al.*, 2002). The variations in species richness and diversity were also recorded across the study sites, and seasons. Species like *Acrida gigantea* and *Oxya hyla hyla* exhibiting higher abundance in months of summer likely benefit from warmer temperatures and increased food availability during this season (Hussain *et al.*, 2017; Sultana *et al.*, 2020).

Acrida turrita emerged as the most abundant species overall, followed by *Oxya hyla hyla* and *Phlaeoba panteli*. These findings suggest potential variations in the diversity and abundance of grasshoppers due to the influence of habitat heterogeneity such as vegetation type and seasonal variations in environmental factors on grasshopper communities (Hussain *et al.*, 2017; Kalhoro *et al.*, 2019). The absence of certain species in specific locations (e.g., *Acrida ungarica*, *Hieroglyphus banian*) suggests potential habitat limitations or specific environmental requirements for these species (Akhtar *et al.*, 2012).

The diversity indices indicated moderately diverse grasshopper populations across the study area. We did not expect a great amount of change in the diversity patterns among sites due to the homogeneity of environmental factors from a general perspective but seasonal variations were hypothesized. Our sites presented variations in plant communities and anthropogenic activities. These factors, as expected, influenced the distributional patterns of grasshoppers. Additionally, investigating diversity patterns within locations and across seasons offered a more clear understanding of the factors influencing grasshopper communities. This study provides valuable baseline data on grasshopper diversity and abundance in district Gujrat.

Conclusions and Recommendations

We documented that the Acrididae family and the genus *Acrida* were dominant in sites through all seasons. Species composition did not vary greatly across locations but through seasons highlighting the influence of changes in environmental factors. Detailed surveys across other locations especially in association with crops and other types of vegetation are recommended for better insight.

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Novelty Statement

This is a preliminary study to explore the diversity of grasshoppers in different locales. The findings will help to understand the local biodiversity, conservation, and management of grasshoppers.

Author's Contribution

MH conceived the idea, planned, supervised the research work, analyzed data, and critically reviewed the manuscript. SNK conceived the idea, and performed data collection. AN, SHS, UZ, and AI helped in data analysis and manuscript writing editing.

Conflict of interest

The authors have declared no conflict of interest.

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