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Research Article

Macromoths (Erebidae: Lepidoptera) and Geometer Moths (Geometridae: Lepidoptera) Species Diversity in Central Sindh, Pakistan

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Abstract: Moths are primarily nocturnal, phytophagous, pests of agriculture, night pollinators, and potential bioindicators. The current study is the first to provide information on the diversity, richness, and abundance of moth species in central Sindh, Pakistan. Moths were collected by light traps, light sheets, and insect nets. A total of 517 specimens were collected during four seasons (Winter, Spring, Summer, and Autumn) and sorted out into 2 families. Moreover, Family Erebidae was sorted out into 3 subfamilies (Arctinae, Calpinae, and Erebinae) of 5 genera (*Utethesia, Chalciope, Creatonotus, Grammodes,* and *Eudocima*) with 8 species (*Utethesia pulchella* Linnaeus 1758, *Utethesia lotri*x Cramer 1789, *Chalciope mygdone* Cramer 1775, *Creatonotus transiens* Walker 1855, *Grammodes geometrica* Fabricius 1775, *Grammodes stolida* Fabricius 1775, *Eudocima phalonia* Linnaeus 1763, and *Eudocima maternal* Linnaeus 1767) while family Geometridae was sorted out into 3 subfamilies (Sterrhinae, Ennominae, and Geometrinae) of 3 genera (*Scopula, Isturgia,* and *Microloxia*) with 5 species (*Scopula pulchella* Fabricius 1794, *Scopula minorata* Boisduval 1833, *Isturgia disputaria* Guenee 1858, *Isturgia Pulinda* Walker 1860, and *Microloxia herbaria* Hubner 1800). However, the family Erebidae was found to be the most prevalent with 8 species while the family Geometridae was found to be the least prevalent with 5 species. However, the family Geometridae was found to be highest in abundance with 305 specimens while the family Erebidae was found to be lowest in abundance with 212 specimens. According to the localities, the highest value (0.91) of Simpson's index (D) was recorded for Matiari; while the lowest value (0.86) was recorded for Jamshoro. The survey locations featured varied moth fauna, as evidenced by the fact that Matiari was recorded as the highest value (2.394) Shannon index (H) while Jamshoro was recorded as the lowest value (2.034).

Keywords: Diversity, Erebidae, Geometridae, Moths, Pakistan.

1. INTRODUCTION

Diversity is the first step in creating conservation objectives for all arthropods [1]. In most cases, it pertains to variation within and between species, and ecosystems. The total known species of Lepidoptera comprise about 10% of all animal species, which is comparable to the total known species of flowering plants [2]. There is little information and little study on Lepidoptera due to researchers' propensity for working on less diverse taxa [3]. Nearly 200,000 distinct Lepidopteran species exist [4], of them about 6,000 species are economically significant [5].

Moths are bioindicators that are sensitive to environmental changes [6]. Moths are members of the suborder Heterocera of Lepidoptera order, which plays a significant role in the forest environment as herbivores and a source of food for parasitic and predatory species [7].

Moths constitute several families, from them Erebidae constitutes the largest family [8]. Geometridae is a diverse family of moths that act as dependable sensors of environmental change [9]. A number of moths are pollinators but due to nocturnal activity further, they don't seem to take an interest in research [7]. They are also recognized as crucial for ecosystem services due to their role as pests on a variety of agricultural crops [10], food for mammals [9], bird fauna [11], and their role in night pollination [12]. In the world, there are over 127,000 different species of moths, and

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more than 12,000 of them have been found in India [13]. Moths are among the most stunning creatures in nature, making up 91% of all species in the Lepidoptera order, and they are extremely important to the ecosystem [14].

Morphological characteristics, including labial palpi, reception apparatus construction, and wing venation, have been used to isolate the Lepidoptera taxon since the significance of outer genital morphology has recently become apparent, the scientific categorization and phylogeny of Lepidoptera have been well understood [15]. A few analyses on the overall external morphology of several lepidopteron groups have been conducted: among them systematics importance of the male genitalia in micro-Lepidoptera [16]. However, previously no detailed work was reported from Sindh province except a few reports which are uncompleted so there is a great need to work on this important group of moths, and all the species in this paper are reported first time from central Sindh.

This research assumes significant importance as it addresses a critical gap in scientific understanding. To date, no comprehensive study has explored the diversity, richness, and abundance of moth species in central Sindh, Pakistan. This pioneering study sheds light on the region's moth richness, abundance, and taxonomy, making it the first of its kind in the area. Using a combination of collection methods, 517 specimens were categorized into two families: Erebidae and Geometridae with distinct subfamilies, genera, and species. The findings reveal variations in prevalence and abundance, with the Erebidae family exhibiting higher prevalence but lower abundance compared to Geometridae. The variation in Simpson's and Shannon's indices across survey locations underscores the diverse moth fauna present in different parts of the region. This research enriches agricultural practices by identifying potential bioindicators for pest control and pollination in central Sindh, Pakistan, aiding in sustainable ecosystem management and enhanced crop productivity.

2. MATERIALS AND METHODS

2.1. Study Site

The study was carried out during four seasons of 2020 and 2021 in three localities (Jamshoro, Tandojam, and Matiari) of Central Sindh, Pakistan. The highest temperature in Central Sindh normally ranges from 109 to 120 °F (43 to 49 °C) (Pak Met Department). These localities in Sindh are Agricultural hubs that occupy a diverse fauna of moth species. Latitude longitude and altitude of these localities are also recorded (Table 1).

2.1.1. Collection

Moths were captured by insect net, light trap, and light sheets [17, 18]. Light traps and light sheets were operated from 09:00 pm. to 03:00 am. A mercury vapor lamp was used to power the light trap and light-sheet (7 × 4 meters, and 250 W). In light sheets, the light was positioned so that it illuminated the entire white sheet, which was strung between two neighbouring trees. The captured specimens perished from ethyl acetate vapours. Later, samples were dried, stretched, and pinned before being placed in entomological boxes.

2.1.2. Identification and preservation

For the identification of moth current taxonomic keys, literature, and genitalia dissection was accomplished. The categorization scheme of genital dissection was modified [19, 20]. A stereo binocular Microscope (BD-45T1) was used for identification. The significant diagnostic features were identified, and images were taken. The location of the collection, date of collection, and collector's name was appropriately listed on the labels for the moths. At the Department of Zoology, University of Sindh Jamshoro, the captured specimens were deposited.

2.2. Diversity Index's

2.2.1. Shannon Weiner index (1963)

The Shannon index (1963) (H), was used to determine the moth fauna's diversity.

Table 1. Showing the longitude, latitude, and altitude of sampling sites.

Locality	Longitude	Latitude	Altitude/ Elevation (m)
Jamshoro	67.952363	25.6250777	120
Tandojam	68.530677	25.428073	29
Matiari	68.5008666	25.6430861	29

The following equation used to determine the Shannon index:

$$H' = [\Sigma Pi \ In \ Pi]$$

Where H is the Shannon-Wiener indicator of species diversity.
Pi = the percentage of the entire sample that belongs to the species.
and ln = Natural log in calculating

In order to determine species dominance and evenness, the Simpson's index (D) and the Evenness index (E) are analyzed [21].

2.2.2. Simpson diversity index

SDI = 1- Σn (n-1)
N (N-1)
Where,
Σ = sum of (total)
Where n is the total number of species, while N is the overall number of individuals in each species.

3. RESULTS

Studies on moth diversity were carried out over 8 months in 2020 and 2021. The study of the moth fauna of two distinct families Erebidae and Geometridae (Lepidoptera), from different agricultural areas of Central Sindh has been conducted. During the current investigation, 517 moth specimens represent 13 species, 8 genera, 6 subfamilies, and 2 families (Figure 1). Eight species of the family Erebidae and five species of the family Geometridae were captured from 3 studied localities. Due to the controversial status of some species, all species were identified via genital dissection and external morphology.

Based on the number of species, the family Erebidae had the highest species richness, with 8 species followed by Geometridae with 5 species, while Erebidae recorded as lowest in abundance (Table 2). In family Geometridae, *Scopula pulchella,* was most prevalent specie (15.47%) followed by *Microloxia herbaria* (14.50%), where *Isturgia*

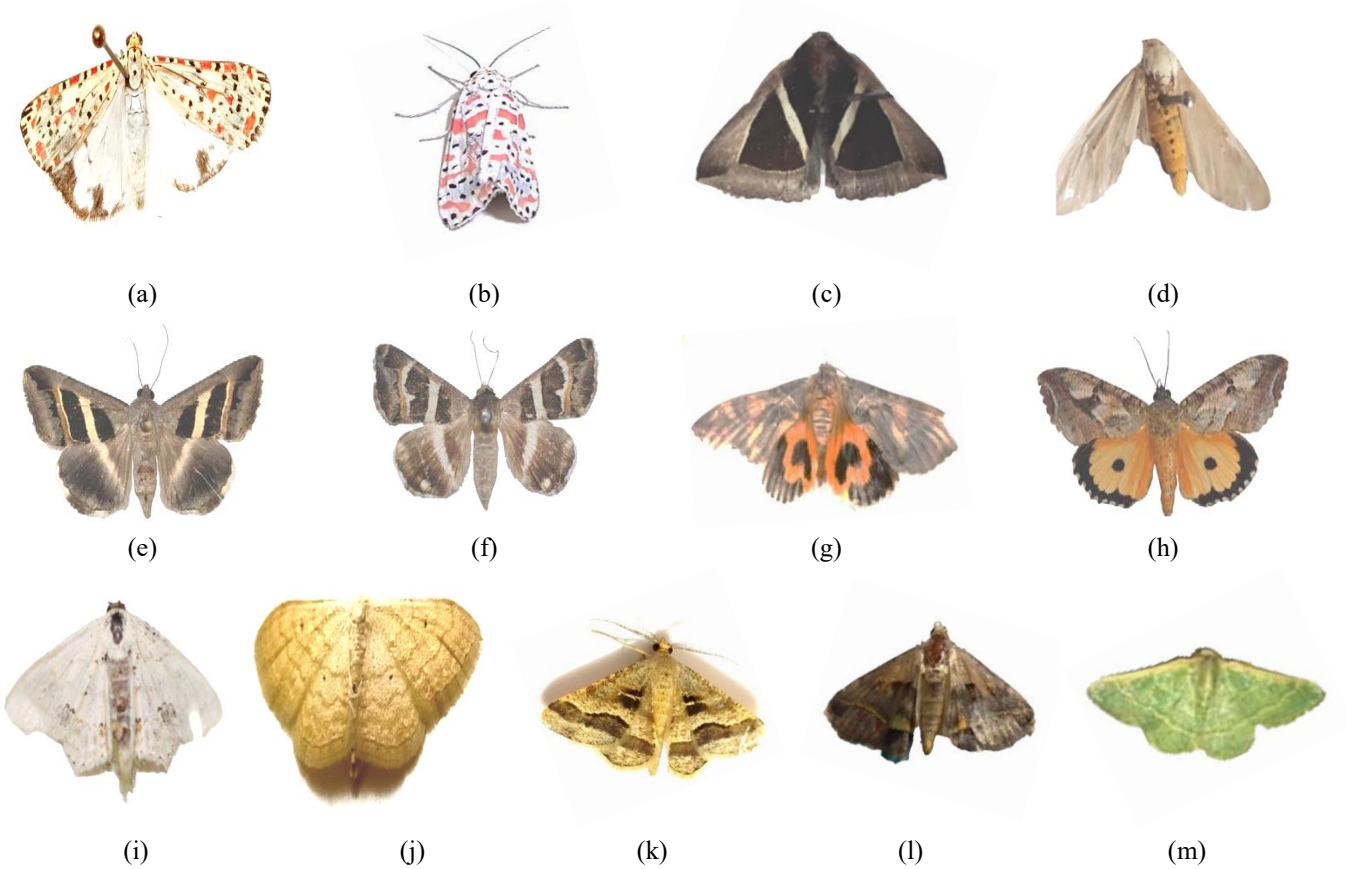

Fig. 1. (a) *Utethesia pulchella*, (b) *Utethesia lotrix*, (c) *Chalciope mygdon*, (d) *Cretonotus transiens*, (e) *Grammodes geometrica*, (f) *Grammodes stolida*, (g) *Eudocima phalonia*, (h) *Eudocima materna*, (i) *Scopula pulchellata*, (j) *Scopula minorata*, (k) *Isturgia disputaria*, (l) *Isturgia pulinda*, and (m) *Microloxia herbaria*.

Table 2. Showing collected species of Moths from three study localities of Central Sindh Pakistan.

Species	No: Specimen	Subfamily	Family	Species Author
Utethesia pulchella	38	Arctinae	Erebidae	Linneaus, 1758
Utethesia lotrix	29	Arctinae	Erebidae	Cramer 1779
Chalciope mygdone	20	Erebinae	Erebidae	Cramer 1777
Creatonotus transiens	24	Arctinae	Erebidae	Walker, 1855
Grammodes geometrica	28	Erebinae	Erebidae	Fabricius 1775
Grammodes stolida	18	Erebinae	Erebidae	Fabricius 1775
Eudocima phalonia	25	Calpinae	Erebidae	Linnaeus, 1763
Eudocima materna	30	Calpinae	Erebidae	Linnaeus, 1767
Scopula pulchellata	80	Sterrhinae	Geometridae	Fabricius 1794
Scopula minorata	45	Sterrhinae	Geometridae	Boisduva 1833
Isturgia disputaria	62	Ennominae	Geometridae	Guenee 1858
Isturgia pulinda	43	Ennominae	Geometridae	Walker 1860
Microloxia herbaria	75	Geometrinae	Geometridae	Hubner 1800
Abundance (N)	517			
Richness (S)	13			

pulinda was the least prevalent species (8.31%). In the family Erebidae, *Utethesia pulchella* was the most dominant (7.35%), while *Grammodes stolida* was recorded as least dominant (3.48%) (Tables 3).

Simpson's Diversity Index (D), Shannon Diversity Index (H), and Evenness (E) were calculated across the survey and were 0.91, 0.394, and 0.964, respectively, (Table 4), indicating that the moth fauna is diversified. The highest value of (D) was measured in Matiari (0.91) followed by Tandojam (0.89) and the least value were recorded from Jamshoro (0.86). Matiari recorded the highest value of H (2.394), followed by Tandojam (2.23), and Jamshoro recorded the lowest value (2.034). Matiari displayed the greatest species richness (12), followed by Tandojam (11), and Jamshoro displayed the least amount of species (9). The maximum abundance was recorded from Matiari (212), followed by Tandojam (162), and the least abundance was recorded from Jamshoro (143). The highest value of evenness was obtained from

Table 3. Showing Locality wise collection of Moth species from three study localities.

Species	Localities			Total	Percentage
	Jamshoro	Tandojam	Matiari		
Utethesia pulchella	10	16	12	38	7.35%
Utethesia lotrix	8	12	9	29	5.69%
Chalciope mygdon	0	8	12	20	3.86%
Creatonotus transiens	0	5	19	24	4.64%
Grammodes geometrica	0	0	28	28	5.41%
Grammodes stolida	0	2	16	18	3.48%
Eudocima phalonia	8	12	5	25	4.83%
Eudocima materna	11	0	19	30	5.80%
Scopula pulchellata	37	22	21	80	15.47%
Scopula minorata	10	18	17	45	8.70%
Isturgia disputaria	28	12	22	62	11.99%
Isturgia pulinda	11	32	0	43	8.31%
Microloxia herbaria	20	23	32	75	14.50%
R=13	N=143	N=162	N=212	517	100%

Matiari (0.964), while Tandojam had the second-highest value (0.93), and the lowest value (0.926) was recorded from Jamshoro (Table 4).

Sindh is blessed with four distinctive seasons (winter, spring, summer, and autumn), 517 moth specimens from 13 variant species have been collected in four seasons of Central Sindh over the course of the research period. It was observed that moths were active throughout the whole research period, with notable variations in abundance and species richness across these seasons. The percentage of family Geometridae (58.99%) was recorded as highest as compared to family Erebidae (41.00%), (Table 5). The highest quantity and diversity of moths were observed during the spring season throughout all families, with 263 individuals representing 13 species and accounting for 50.87% of the total capture. Of these, 147 individuals belonged to the Geometridae and 116 to the Erebidae. The summer season was reported to be the second favorite season, especially for the moth of the family Geometridae with 61 individuals from 5 species representing 20% of the population, followed by 42 individuals from 8 species of the family Erebidae, representing 19.81%. Winter had the third-highest diversity with 77 species of Family Geometridae, accounting for 25.24% of all species, however, in Autumn, this family had the lowest diversity, 20 accounting for 6.55%, while the number of moths of family Erebidae was lower in the winter than the autumn, 26 collected, representing 12.26% and in autumn 28 specimens found representing 13.20%. (Table 5), showing a seasonal abundance of moth families.

4. DISCUSSION

Pakistan is an agricultural country in which the agriculture sector contributes approximately 25.6% of GDP (Gross domestic production) [22]. Among insects, Lepidoptera is the second largest and diverse order of insects. Lepidoptera comprises of more than 180,000 species belonging to 46 superfamilies and 126 families [23]. More than 28000 species are butterflies. In Pakistan approximately 5000 insect species are present among them 400 species are butterflies and moths [24]. Lepidopteran insects are butterflies, moths, and skippers that are widely distributed in agro-environment. The abundance of lepidopteran insects depends upon many factors such as type of vegetation and availability of hosts). The diversity and occurrence of lepidopteran fauna in the cropland ecosystem is mainly due to their feeding habits [26]. In this study, we investigated the moth diversity in the biodiversity-rich areas of Sindh, Pakistan with the intention of recording the macro and geometer moth species found in the agroecosystem, species-rich families, and habitats with high diversity.

Table 4. Showing measurement of Simpson diversity, Shannon diversity index, Species richness, evenness, and abundance of moths from three study localities of Central Sindh.

Locality	Simpson Diversity Index (D)	Shannon Diversity Index (H)	Evenness (E)	Richness (S)	Abundance (N)
L1 (Jamshoro)	0.86	2.034	00.926	9	143
L2 (Tandojam)	0.89	2.23	00.93	11	162
L3 (Matiari)	0.091	2.394	00.964	12	212

Table 5. Showing seasonal variation in abundance of family Erebidae and Geometridae.

Seasons	Months of 2020 and 2021	Erebidae	Geometridae	Total	Percentage
	December 2020 and February 2021	26	77	103	19.92%
	March and April 2021	116	147	263	50.87%
	May and August 2021	42	61	103	19.92%
	October and November 2021	28	20	48	9.28%
	Total	212	305	517	100%
	Percentage	41.00%	58.99%	100%	
Winter	Spring	Summer		Autumn	

The percentage of family Geometridae (58.99%) was recorded as highest as compared to family Erebidae (41.00%). Based on the number of species, the family Erebidae had the highest species richness, with 8 species followed by Geometridae with 5 species, while Erebidae recorded as lowest in abundance. In family Geometridae *Scopula pulchella*, was most prevalent specie (15.47%) followed by *Microloxia herbaria*, (14.50%) where *Isturgia pulinda* was the least prevalent species (8.31%). In family Erebidae *Utethesia pulchella* was the most dominant (7.35%) while *Grammodes stolida* recorded as least dominant (3.48%). The study's findings also highlight variations in species distribution across different survey locations, as demonstrated by the calculated Simpson's index and Shannon index values.

Previous studies on species richness of moths reveal that some are on par with the current study, and some have deviations. Some researchers have revealed that moth species richness is high in agroecosystems and have suggested possible reasons for this observation [26, 27]. Moths are widely distributed in agro-environment, Patil *et al*. [27] described that the abundance of moths depends upon many factors such as type of vegetation, availability of hosts, and presence of predators and parasitoids.

It has been reviewed that diversity patterns suggest that farmland abandonment is likely to positively affect both overall macro-moth diversity and forest macro-moth diversity and to negatively affect species diversity of non-forest macro-moth species [28 - 30]. Our results also show that habitat diversity is important to maintain the diversity of macro and geometer moths.

Several moths are pollinators but due to nocturnal activity of some moths, it is difficult to find them during day time [7]. They are also recognized as crucial for ecosystem services due to their role as pests on a variety of agricultural crops [10], food for mammals [9], bird fauna [11], and their role in night pollination [12]. In our study, we have 7 species (*Utethesia pulchella, Utethesia lotrix, Chalciope mygdon, Grammodes geometrica, Grammodes stolida, Eudocima phalonia,* and *Eudocima materna*) as pest of various agricultural crops.

5. CONCLUSIONS

In conclusion, this research provides valuable insights into the diversity, richness, and abundance of macro moths (Erebidae) and geometer moths (Geometridae) species in central Sindh, Pakistan. Through comprehensive collection methods across four seasons, a total of 517 specimens were identified, revealing 8 species within the Erebidae family and 5 species within the Geometridae family. Notably, Erebidae exhibited greater species prevalence, while Geometridae demonstrated higher abundance. The study's findings also highlight variations in species distribution across different survey locations, as demonstrated by the calculated Simpson's index and Shannon index values. This research contributes to the understanding of moth populations in the region and lays the foundation for further ecological investigations and conservation efforts.

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7. CONFLICT OF INTEREST

The authors declare no conflict of interest.

8. REFERENCES

1. R.G. Gillespie. Naivete and novel perturbations: Conservation of native spiders on an oceanic island system. *Journal of Insect Conservation* 3: 263–272 (1999).
2. A. Srivastava. Taxonomy of moths in India. *Published by International Book Distributors. Deheradun, India* (2002).
3. S.A. Gurule, and S.M. Nikam. The moths (Lepidoptera: Heterocera) of northern Maharashtra a preliminary checklist. *Journal of Threatened Taxa* 5(12): 4693-4713 (2013).
4. A.G. Butler. Illustrations of typical specimens of Lepidoptera: Heterocera in the collection of the British museum. *Printed by order of the Trustees, London* pp. 1877-93 (1889).
5. B.C. Zhang. Index of Economically Important Lepidoptera. *Wallingford: CAB International* pp. 599 (1994).
6. K. Enkhtur, G. Brehm. B. Boldgiv, & M. Pfeiffer.

Effects of grazing on macro-moth assemblages in two different biomes in Mongolia. *Ecological Indicators* 133: 108421 (2021).
7. K. Sivasankaran. T.B. Thangadurai and S. Ignacimuthu. Studies on external genitalial morphology of subfamily Catocalinae (Lepidoptera: Noctuidae). *Journal of Research in Biology* 8: 631-642 (2011).
8. K. Enkhtur, B. Boldgiv, and M. Pfeiffer. Diversity and distribution patterns of geometrid moths (Geometridae, Lepidoptera) in Mongolia. *Diversity* 12: 186 (2020).
9. N. Vaughan. The diets of British bats (Chiroptera). *Mammal Review* 27: 77-94(1997).
10. A.K. Sharma, and U.K. Bisen. Taxonomic documentation of insect pest fauna of vegetable ecosystem collected in light trap. *International Journal of Environmental Science: Development and Monitoring* 4: 1-8 (2013).
11. W.G. Wilson, S.P. Harrison, A. Hastings, and K. McCann. Exploring stable pattern formation in models of tussock moth populations. *Journal of Animal Ecology* 68: 94-107 (1999).
12. C.J. Macgregor, M.J. Pocock, R. Fox, and D.M. Evans. Pollination by nocturnal Lepidoptera, and the effects of light pollution: a review. *Ecological Entomology* 40: 187-198 (2015).
13. K. Chandra. Moth diversity of Madhya Pradesh and Chhattisgarh, India, and its conservation measures. In: Proceedings of the First South East Asian Lepidoptera Conservation Symposium, Hong Kong. R.C. Kendrick (Ed.), pp. 49-61 (2007).
14. W.T. Blanford, and G.F. Hampson (Eds.). The Fauna of British India including Ceylon and Burma. *Taylor and Francis, Red Lion Court, Fleet Street, London* (1892).
15. G.T. Bethune-Baker. XI. Notes on the Taxonomic value of Genital Armature in Lepidoptera. *Transactions of the Royal Entomological Society of London* 62: 314-338 (1914).
16. C. Heinrich. Some Lepidoptera likely to be confused with the pink bollworm. *Journal of Agricultural Research* 20: 807-836 (1921).
17. J.D. Prins. Lepidoptera Collection Curation and Data Management. *InTech publishers* Chapter 2, pp. 19 (2017). DOI: 10.5772/intechopen.70925.
18. G. Brehm. A new LED lamp for the collection of nocturnal Lepidoptera and a spectral comparison of light-trapping lamps. *Nota Lepidopterologica* 40: 87-108 (2017).
19. J.R. Eyer. The morphological significance of the juxta in the male genitalia of Lepidoptera. *Bulletin of the Brooklyn Entomological Society* 21: 32-37 (1926).
20. E.J. Van Nieukerken, L. Kaila, I.J. Kitching, N.P. Kristensen, D.C. Lees, J. Minet, and A.Z. wick. Order Lepidoptera Linnaeus, 1758. In: Animal Biodiversity: An outline of higher classification and survey of taxonomic richness. Z-Q. Zhang (Ed.). *Zootaxa, Magnolia Press* pp. 212-221 (2011).
21. A. Magurran. Measuring Biological Diversity. *Blackwell Publishing, Malden, MA, USA* (2004).
22. A.A. Chandio, J. Yuansheng, and H. Magsi. Agricultural Sub-Sectors Performance: An Analysis of Sector-Wise Share in Agriculture GDP of Pakistan. *International Journal of Economics and Finance* 8(2): 156-162 (2016).
23. W. Zhang, C. Shih, and D. Ren. Lepidoptera – Butterflies and Moths 619. In: Rhythms of Insect Evolution: Evidence from the Jurassic and Cretaceous in Northern China. D. Ren, C. Shih, T. Gao, Y. Yao, and Y. Wang (Eds). *John Wiley & Sons, Hoboken, NJ* Chapter 27 (2019).
24. M.I. Khan, H. Ullah, Suleman, M.A.S. Khan, N. Muhammad, S. Zada and S. Hussain. A Review on Diversity of Butterfly Fauna in Pakistan. *World Journal of Zoology* 10: 313-317 (2015).
25. S. Maalik, S. Mushtaq, N. Rana, N. Ehsan, N. Bano, and A. Hafeez. Estimation of diversity-relative abundance and temporal distribution of lepidopteran species from agro-ecosystem of district Faisalabad, Pakistan. *Journal of Agricultural Research* 60(4): 305-316 (2022).
26. P. Gunathunga, C.D. Dangalle, and N. Pallewatta. Diversity and Habitat Preferences of Moths (Insecta: Lepidoptera) in Indikadamukalana, a Lowland Wet Zone Forest in Sri Lanka. *Journal of Tropical Forestry and Environment* 12(1): 10-23 (2022).
27. A. A. Baikar and K. V. Naik. Biology of fruit borer, *Helicoverpa armigera* (Hubner) on chilli under laboratory conditions. *Plant Archives* 16(2): 761-769 (2016).
28. D.D. de Miranda, H.M. Pereira, M.F.V. Corley, and T. Merckx. Beta diversity patterns reveal positive effects of farmland abandonment on moth communities. *Scientific Reports* 9: 1549 (2019).
29. M.M. Trigunayat, and K. Trigunayat. On the diversity of moth fauna of Keoladeo National Park, Bharatpur. *International Journal of Recent Scientific Research* 12(1): 40515-40518 (2021).
30. D. Rabl, B. Gottsberger, G. Brehm, F. Hofhansl, and K. Fiedler. Moth assemblages in Costa Rica rain forest mirror small-scale topographic heterogeneity. *Biotropica* 52: 288–301 (2020).