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**Research Article****Diversity and relative abundance of Order Lepidoptera from agro-ecosystem of District Sialkot, Pakistan**Sadia Maalik¹, Nehal Khalid¹, Sajida Mushtaq¹, Moazama Batool¹, Ayesha Hafeez¹, Nazia Ehsan², Naheed Bano³¹ Government College Women University Sialkot, Punjab, Pakistan.² Department of Wildlife and Fisheries, University of Agriculture, Faisalabad, Punjab, Pakistan.³ Faculty of Veterinary and Animal Sciences, MNS-University of Agriculture, Multan, Punjab, Pakistan.**ABSTRACT**

Moths, skippers, and butterflies are all members of the second most well-known and diverse order of insects, the order Lepidoptera. In agronomic domains, lepidopterans are ecologically important insects that serve as both pollinators and pests. Agro-ecosystems support a diverse range of pests and beneficial insects. Agro-ecosystems support a diverse range of pests and beneficial insects. During the current study, the diversity and relative abundance of Lepidopteran species (including both adults and larvae) were analyzed from the selected crops i.e. fodder, brassica, wheat, and vegetables from agro-ecosystems of district Sialkot, Pakistan. Sampling was done through the quadrat and sweep net methods from March 2021 to June 2021. A total of 2013 Lepidopteran specimens constituting 26 genera and 29 species belonging to 10 families were recorded from these crops available at the selected locales of Sialkot district. The fodder crop was found to be rich in Lepidopterans manifesting a relative abundance of 53.40% followed by brassica (25.88%), vegetables (19.82%), and least was in wheat (0.89%). Maximum relative abundance was noticed in May (33.48%) followed by April (31.84%), March (20.07%), and lowest in June (14.61%). Family Pieridae was the most abundant family with a relative abundance of 41.03% followed by the family Noctuidae (39.29%). The most dominant species was *Helicoverpa armigera* showing a relative abundance of 17.44%. The fodder crop ($H' = 2.999$) and the month of May ($H' = 2.8053$) demonstrated the highest diversity among all the data evaluated by the Shannon-Weiner diversity index (H'). It is concluded that district Sialkot has a diversified Lepidopteran fauna. For the purpose of assessing their diversity, abundance, and distribution in upcoming conservation and pest management research, the current study may assist in identifying beneficial Lepidopteran species and pests in agro-ecosystems.

Keywords: Lepidoptera; relative abundance; quadrat; sweep net; shannon weiner diversity index.

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INTRODUCTION

Agro ecosystems have more biodiversity than any other area (Ramzan et al., 2021) because they provide habitats to many insects with positive and detrimental impacts. Insects comprise about 66% of this planet's recognized species acting as pollinators, pests, biological control agents, food for other animals, decomposers, and pollution indicators (Jankielsohn, 2018; Noriega et al., 2018). Moreover, their trophic relationships maintain the ecosystem's microhabitats by controlling various ecological activities (Abdala-Roberts et al., 2019). Of all the insect species, about 10 % is contributed by Lepidopterous insects (Willmer, 2011). Order Lepidoptera is the second major and diversified order of the class Insecta having more than 180,000 reported species classified in 46 superfamilies and 126 families (Khan et al., 2023). In 1735 Linnaeus coined the word 'Lepidoptera' meaning 'scaly winged'.

Lepidopterans are distinguished from other insects by densely pigmented scales on the wings. This order is represented by butterflies, moths, and skippers. Lepidoptera is a remarkable order having global distribution and consisting of silk producers, food for animals, environmental biosensors, pollinators, pests, and performing quantitative assessments of insect populations (Haroon et al., 2013; Mal et al., 2013).

Lepidopterans play dual roles in agro-ecosystems: while their larval stages are pests with chewing mouthparts, that damage the crops, decrease photosynthesis, and ultimately reduce the carbohydrate yield (Maish, 2019). While adult moths and butterflies are helpful pollinators (Khyade, 2019; Choudhary and Mallya, 2019)

Globally recorded species of butterflies reach about 28000, with 80% of those present only in tropical areas. There are about 5000 documented insect species from Pakistan, 400 of which are moths and butterflies (Khan et al., 2015; Attaullah et al., 2018; Bibi et al., 2022). Lepidopterans are highly abundant and prevalent insects (Khan et al., 2023). Their diversity and abundance depend on the accessibility to host plants and climatic conditions (Dev et al., 2020). Species abundance is an important factor in estimating the probable future distribution of species, approximating and comprehending their decline and habitats (Piccini et al., 2023). Biodiversity is a determinant of the health of an ecosystem (Chowdhury and Soren, 2011). Therefore, diverse ecosystems are more stable than poorly rich ecosystems. Due to the ecological significance of lepidopterans, the current study was carried out to explore the diversity and relative abundance of lepidopteran species from the agro-ecosystem of district Sialkot, Pakistan.

MATERIALS AND METHODS

Study Area

The study was conducted from four localities (Tehsil Sialkot, Tehsil Pasrur, Tehsil Daska, and Tehsil Sambrial) of district Sialkot. It plays an important role in the industrial and agricultural development of Pakistan (Hussain et al., 2017). District Sialkot is situated in the northeast of Punjab around 74° 31' of East longitude and 32° 30' North latitude at 256 m elevation from sea level. The region experiences a cold winter and scorching, humid summer with an average temperature of 22 °C - 46 °C (Nasir et al., 2016; Khan, 2019).

Sampling Method

Lepidopteran fauna was collected from March 2021 to June 2021 from the selected crops namely fodder, brassica, wheat, and vegetables available at various localities of district Sialkot. Sampling was performed fortnightly from each locality in clear weather between 8 am to 12 pm by hand picking, quadrat, and sweep net methods. As per protocol (Ruby et al., 2011) four quadrats (measuring area of 1m²) were applied in each field per locality with two random quadrats at the center and two at the corners making a total of eight quadrats per sampling. A sweep net of 60 cm long cotton fabric having a diameter of 30 cm was used for sample collection and for the sampling of ground-dwelling fauna, hand-picking was employed.

Preservation

Two types of preservation i.e. dry and wet were carried out. Adults were dry-preserved in insect boxes whereas larvae were wet-preserved in glass vials containing 70% alcohol with one or two drops of glycerin to avoid hardness and brittleness. All the samples were properly tagged with crop name, sample number, species name, date, and method of sampling (Soomro et al., 2012; Sultana et al., 2013).

Species identification: All the samples were sorted and their morphological identification up to species level was carried out by consulting different identification keys such as Borror and DeLong (2005), "Fauna of British India" by Talbot (1978), "Butterflies of Pakistan" by T. J. Roberts (2001), available literature, and different keys accessible on the internet.

Statistical Analysis

MS Excel 365 was used for the computation of relative abundance. Evenness and Shannon-Weiner diversity index (H') were analyzed by using the Paleontological Statistics software package (PAST) version 3.0 reference at significance level $\alpha = 0.05$ (Sebua and Nuñez 2020). t-test was performed to determine significant differences in diversity between the recorded data (Majeed et al., 2021).

RESULTS AND DISCUSSION

A total of 2013 samples belonging to 10 families, 26 genera, and 29 species of the order Lepidoptera were collected from fodder, vegetables, wheat, and brassica crops available at four tehsils of district Sialkot. Family-wise analysis of relative abundance manifested that Pieridae was the most abundant (41.03%) family, followed by Noctuidae (39.29%), Lycaenidae (6.46%), Geometridae (3.38%), Nymphalidae (3.08%), Hesperidae (1.64%), Erebidae (1.59%),

Sphingidae (1.39%), Papilionidae (1.19%), and least abundant was Pyralidae (0.94%) (Figure 1). A total of 29 species were collected including *Helicoverpa armigera* (17.44%), followed by *Piers brassicae* (11.87%), *Pieris canidia* (9.74%), *Spodopetra litura* (7.55%), *Colias croceus* (6.76%), *Pontia daplidice* (5.27%), *Spodoptera exigua* (4.27%), *Zizeeria karsandra* (3.53%), *Rhodometra sacraria* (3.38%), *Trichoplusia ni* (3.08%), *Catopsilia pomona* (2.98%), *Agrotis ipsilon* (2.83%), *Belenois aurota* (2.24%), *Mamestra brassicae* (2.19%), *Mythimna separata* (1.94%), *Pelopidas mathias* (1.64%), *Tarucus nara* (1.49%), *Chilades parrhasius* (1.44%), *Vanessa cardui* (1.39%), *Ariadne merione* (1.44%), *Papilio demoleus* (1.19%), *Colias erate* (1.14%), *Eurema hecabe* (1.04%), *Amata phegea* (0.94%), *Ostrinia nubilalis* (0.94%), *Arguis convolvuli* (0.89%), *Euproctis smillis* (0.65%), *Macroglossum belis* (0.5%), and *Danaus chrysippus* (0.25%). The dominant species was *H. armigera* and the least abundant species was *D. chrysippus* (Table 1).

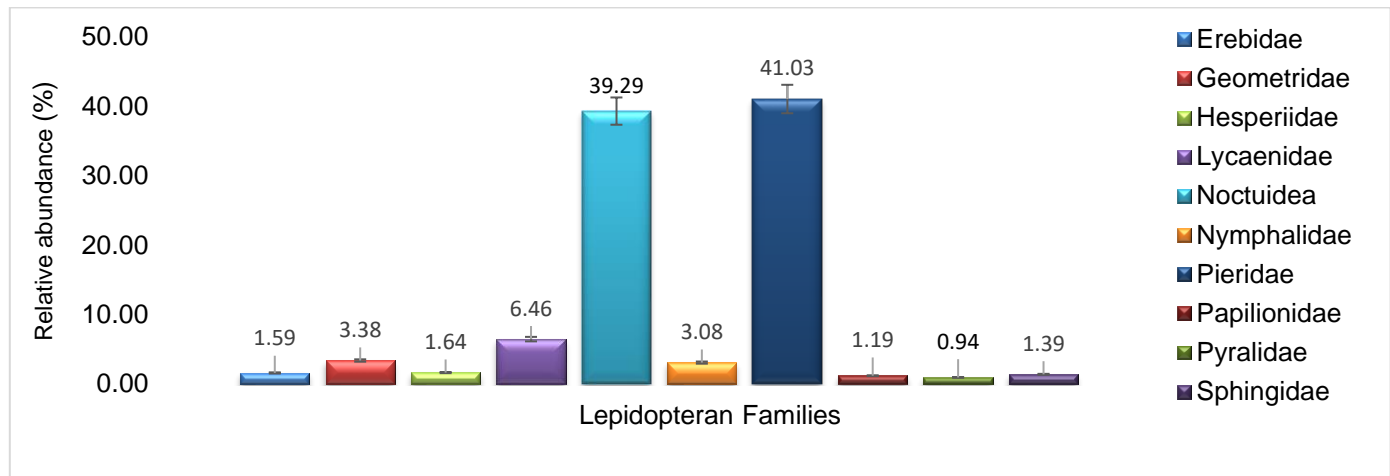


Figure 1. Relative abundance of Lepidopteran families recorded from district Sialkot, Pakistan.

Table 1. Crop-wise relative abundance of Lepidopteran fauna sampled from district Sialkot.

Family	Species	Relative abundance % (No. of individuals)				Total
		Fodder	Brassica	Wheat	Vegetables	
Erebiidae	<i>Amata phegea</i>	0.94 (19)	-	-	-	0.94 (19)
	<i>Euproctis smillis</i>	0.45 (9)	0.20 (4)	-	-	0.65 (13)
Total		1.39 (28)	0.20 (7)	-	-	1.59 (32)
Geometridae	<i>Rhodometra sacraria</i>	2.63 (53)	-	-	0.75 (15)	3.38 (68)
Hesperiiidae	<i>Pelopidas mathias</i>	1.44 (29)	-	-	0.20 (4)	1.64 (33)
Lycaenidae	<i>Chilades parrhasius</i>	1.14 (23)	0.30 (6)	-	-	1.44 (29)
	<i>Tarucus nara</i>	0.65 (13)	-	-	0.84 (17)	1.49 (30)
	<i>Zizeeria karsandra</i>	1.84 (37)	0.94 (19)	0.15 (3)	0.60 (12)	3.53 (71)
Total		3.68 (74)	1.24 (25)	0.15 (3)	1.59 (32)	6.46 (130)
Noctuidea	<i>Agrotis ipsilon</i>	1.79 (36)	0.55 (11)	-	0.50 (10)	2.83 (57)
	<i>Helicoverpa armigera</i>	9.59 (193)	3.48 (70)	-	4.37 (88)	17.44 (351)
	<i>Mythimna separata</i>	1.34 (27)	0.35 (7)	0.10 (2)	0.15 (3)	1.94 (39)
	<i>Mamestra brassicae</i>	0.89 (18)	0.65 (13)	-	0.65 (13)	2.19 (44)
	<i>Spodoptera litura</i>	4.92 (99)	1.04 (21)	-	1.59 (32)	7.55 (152)
	<i>Spodoptera exigua</i>	2.19 (44)	0.99 (20)	-	1.09 (22)	4.27 (86)
	<i>Trichoplusia ni</i>	1.69 (34)	0.84 (17)	-	0.55 (11)	3.08 (62)
Total		22.40 (451)	7.90 (159)	0.10 (2)	8.89 (181)	39.29 (791)
Nymphalidae	<i>Ariadne merione</i>	0.84 (17)	0.45 (9)	-	0.15 (3)	1.44 (29)
	<i>Vanessa cardui</i>	0.94 (19)	0.15 (3)	-	0.30 (6)	1.39 (28)
	<i>Danaus chrysippus</i>	0.15 (3)	0.10 (2)	-	-	0.25 (5)
Total		1.94 (39)	0.70 (14)	-	0.45 (9)	3.08 (62)
Pieridae	<i>Belenois aurota</i>	1.69 (34)	-	-	0.55 (11)	2.24 (45)
	<i>Colias croceus</i>	2.38 (48)	3.43 (69)	0.15 (3)	0.79 (16)	6.76 (136)
	<i>Colias erate</i>	0.84 (17)	-	-	0.30 (6)	1.14 (23)
	<i>Catopsilia Pomona</i>	2.04 (41)	-	-	0.94 (19)	2.98 (60)
	<i>Eurema hecabe</i>	0.70 (14)	0.25 (5)	-	0.10 (2)	1.04 (21)

	<i>Pieris canidia</i>	3.38 (68)	4.92 (99)	0.25 (5)	1.19 (24)	9.74 (196)
	<i>Pieris brassicae</i>	3.92 (79)	6.31 (127)	0.15 (4)	1.44 (29)	11.87 (239)
	<i>Pontia daplidice</i>	2.93 (59)	0.94 (19)	-	1.39 (28)	5.27 (106)
Total		17.88 (360)	15.85 (319)	0.60 (12)	6.71 (135)	41.03 (826)
Papilionidae	<i>Papilio demoleus</i>	0.89 (18)	-	-	0.30 (6)	1.19 (24)
Pyralidae	<i>Ostrinia nubilalis</i>	0.10 (2)	-	-	0.84 (17)	0.94 (19)
Sphingidae	<i>Argus convolvuli</i>	0.65 (13)	-	0.05 (1)	0.20 (4)	0.89 (18)
	<i>Macroglossum belis</i>	0.45 (9)	-	-	0.05 (1)	0.50 (10)
Total		1.09 (22)	-	0.05 (1)	0.25 (5)	1.39 (28)
Grand Total		53.40 (1075)	25.88 (521)	0.89 (18)	19.82 (399)	100 (2013)

Crop-wise Relative Abundance of the Lepidopteran population

Relative abundance was recorded maximum in fodder (53.40%) followed by vegetables (25.88%), brassica (19.82%), and least in wheat crop (0.89%). Family Noctuidae was the dominant family of fodder (22.40%) and vegetables (8.89%). Pieridae was the abundant family in brassica (15.85%) and wheat (0.60%). *H. armigera* was the most abundant species in fodder (9.59%) and vegetables (4.37%). *P. brassicae* (6.31%) followed by *P. canidia* (4.92%) were dominant species from brassica. *P. canidia* was the abundant species in wheat with 0.25% relative abundance (Table 1). Overall percentage contribution of the collected species from the four selected crops revealed that *H. armigera* was the dominant species contributing 17% to all crops followed by *P. brassicae* with a share of 12% and *P. canidia* representing an overall 10% relative abundance (Figure 2).

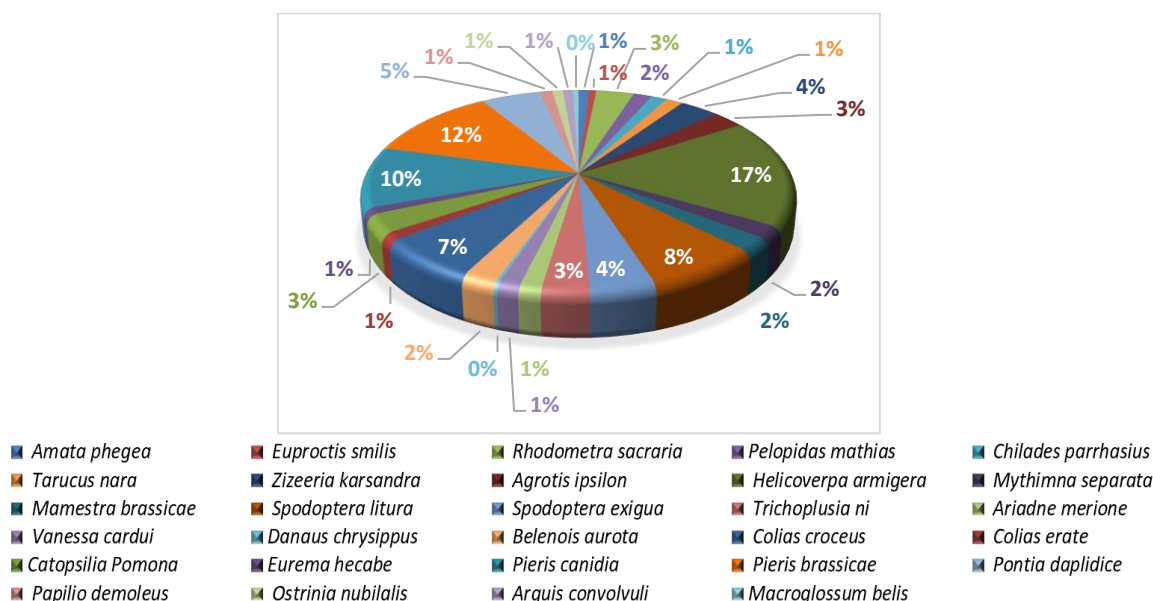


Figure 2. Overall percentage contribution of the collected Lepidopteran species from four crops available in district Sialkot.

Month-wise Relative Abundance of Lepidopterans

The month-wise relative abundance data depicted in table (2) indicates that the maximum number of lepidopteran populations was reported in May (33.48%) followed by April (31.84%), March (20.07%), and June (14.61%). Pieridae was the dominant family of April and March with a relative abundance of 17.29% and 10.23% respectively. Noctuidae was an abundant family throughout May (16.24%) and June (6.36%). *P. brassicae* was documented as the most abundant species during March (3.78%) and April (6.41%) followed by *P. canidia* in March (3.33%) and April (4.77%). *H. armigera* exhibited the highest relative abundance during May (8.99%) while *S. litura* was the most abundant (3.08%) species in June (Figure 3).

Statistical Analysis for the Diversity Evaluation

Table 3 compares the results of the Shannon diversity indices for four selected crops. Fodder was the most diverse crop ($H' = 2.999$) followed by vegetables (2.7862) brassica (2.2908), while wheat (1.692) was the least diverse crop.

Table 2. Month-wise relative abundance of Lepidopteran fauna sampled from district Sialkot.

Family	Species	Relative abundance % (No. of individuals)				Total
		March	April	May	June	
Erebidae	<i>Amata phegea</i>	-	0.25 (5)	0.70 (14)	-	0.94 (19)
	<i>Euproctis smilis</i>	0.50 (10)	0.15 (3)	-	-	0.65 (13)
Total		0.50 (10)	0.40 (8)	0.70 (14)	-	1.59(32)
Geometridae	<i>Rhodometra sacraia</i>	-	0.65 (13)	1.49 (30)	1.24 (25)	3.38 (68)
Hesperiidae	<i>Pelopidas mathias</i>	0.25 (5)	0.45 (9)	0.94 (19)	-	1.64 (33)
Lycaenidae	<i>Chilades parrhasius</i>	0.15 (3)	0.30 (6)	0.75 (15)	0.25 (5)	1.44 (29)
	<i>Tarucus nara</i>	-	0.20 (4)	0.50 (10)	0.79 (16)	1.49 (30)
	<i>Zizeeria karsandra</i>	1.24 (25)	0.75 (15)	1.04 (21)	0.50 (10)	3.53 (71)
Total		1.39 (28)	1.24 (25)	2.29 (46)	1.54 (31)	6.46 (130)
Noctuidae	<i>Agrotis ipsilon</i>	-	0.65 (13)	1.64 (33)	0.55 (11)	2.83 (57)
	<i>Helicoverpa armigera</i>	2.04 (41)	3.97 (80)	8.99 (181)	2.43 (49)	17.44 (351)
	<i>Mythimna separata</i>	0.65 (13)	0.79 (16)	0.35 (7)	0.15 (3)	1.94 (39)
	<i>Mamestra brassicae</i>	0.60 (12)	0.89 (18)	0.55 (11)	0.15 (3)	2.19 (44)
	<i>Spodoptera litura</i>	1.04 (21)	1.29 (26)	2.14 (43)	3.08 (62)	7.55 (152)
	<i>Spodoptera exigua</i>	1.19 (24)	1.34 (27)	1.74 (35)	-	4.27 (86)
	<i>Trichoplusia ni</i>	0.94 (19)	1.29 (26)	0.84 (17)	-	3.08 (62)
Total		6.41 (129)	10.23 (207)	16.24 (325)	6.36 (128)	39.29(791)
Nymphalidae	<i>Ariadne merione</i>	0.89 (18)	0.40 (8)	0.15 (3)	-	1.44 (29)
	<i>Vanessa cardui</i>	0.10 (2)	0.35 (7)	0.84 (17)	0.10 (2)	1.39 (28)
	<i>Danaus chrysippus</i>	0.05 (1)	0.15 (3)	0.05 (1)	-	0.25 (5)
Total		1.04 (21)	0.89 (18)	1.04 (21)	0.10 (2)	3.08 (62)
Pieridae	<i>Belenois aurota</i>	0.10 (2)	0.55 (11)	0.99 (20)	0.60 (12)	2.24 (45)
	<i>Colias croceus</i>	2.68 (54)	3.53 (71)	0.55 (11)	0.00	6.76 (136)
	<i>Colias erate</i>	-	0.30 (6)	0.65 (13)	0.20 (4)	1.14 (23)
	<i>Catopsilia pomona</i>	-	0.55 (11)	1.39 (28)	1.04 (21)	2.98 (60)
	<i>Eurema hecabe</i>	0.35 (7)	0.55 (11)	0.15 (3)	-	1.04 (21)
	<i>Pieris canidia</i>	3.33 (67)	4.77 (96)	1.24 (25)	0.40 (8)	9.74 (196)
	<i>Pieris brassicae</i>	3.78 (76)	6.41 (129)	1.69 (34)	-	11.87 (239)
	<i>Pontia daplidice</i>	-	0.65 (13)	2.68 (54)	1.94 (39)	5.27 (106)
Total		10.23 (206)	17.29 (348)	9.34 (188)	4.17 (84)	41.03 (826)
Papilionidae	<i>Papilio demoleus</i>	0.05 (1)	0.30 (6)	0.65 (13)	0.20 (4)	1.19 (24)
Pyralidae	<i>Ostrinia nubilalis</i>	-	0.15 (3)	0.25 (5)	0.55 (11)	0.94 (19)
Sphingidae	<i>Argus convolvuli</i>	0.15 (3)	0.20 (4)	0.45 (9)	0.10 (2)	0.89 (18)

	<i>Macroglossum belis</i>	-	0.05 (1)	0.10 (2)	0.35 (7)	0.50 (10)
Total		0.15 (3)	0.25 (5)	0.55 (11)	0.45 (9)	1.39 (28)
Grand Total		20.07 (404)	31.84 (641)	33.48 (674)	14.61 (294)	100 (2013)

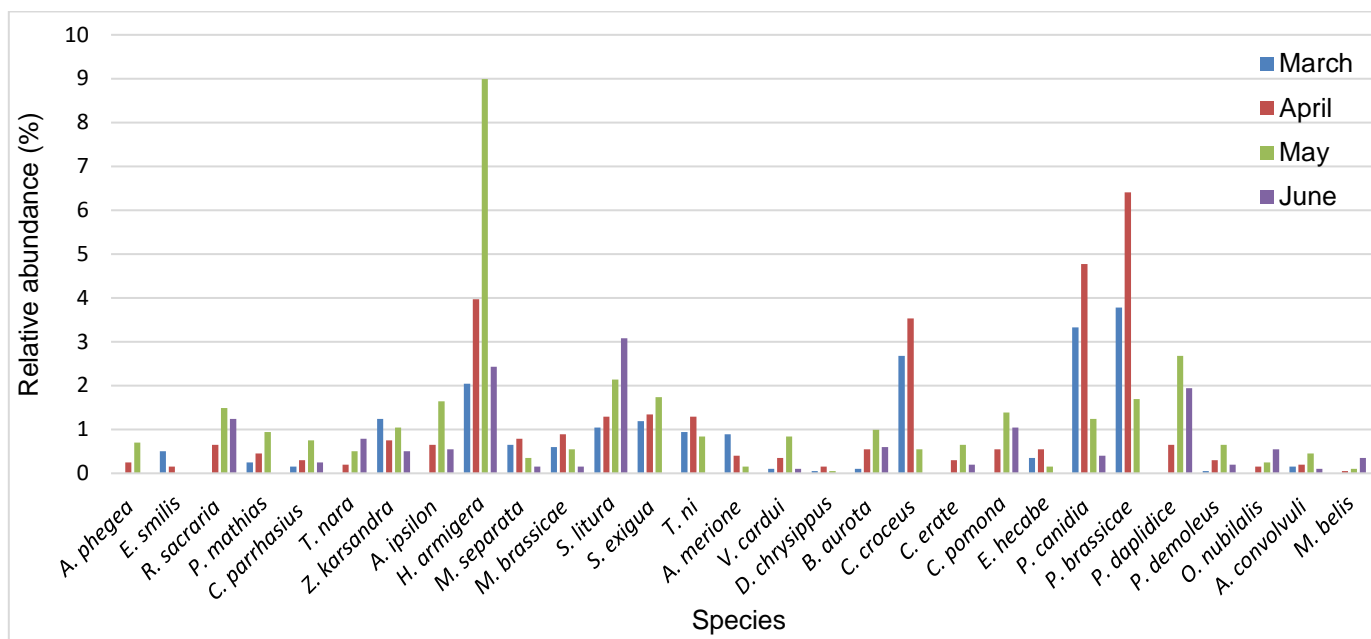


Figure 3. Month-wise relative abundance of the collected Lepidopteran species from district Sialkot, Pakistan.

Maximum diversity variation (t-test value = 14.234) was found for fodder and brassica comparison. Results were significant (P<0.05) for all crops.

Table 3. Shannon-Weiner diversity indices (H') representing differences in Lepidopteran diversity from the selected crops of district Sialkot.

Crops	N1	H'1	E1	N2	H'2	E2	Df	t-test	P-value
Fodder vs Brassica	1075	2.999	0.6919	521	2.2908	0.5491	911.46	14.234	0.000000*
Fodder vs Wheat	1075	2.999	0.6919	18	1.692	0.9051	19.432	9.8483	0.000000*
Fodder vs Vegetables	1075	2.999	0.6919	399	2.7862	0.6488	666.78	4.1028	0.000046*
Brassica vs Wheat	521	2.2908	0.5491	18	1.692	0.9051	22.05	4.3712	0.000243*
Brassica vs Vegetables	521	2.2908	0.5491	399	2.7862	0.6488	880.94	-7.991	0.000000*
Wheat vs Vegetables	18	1.692	0.9051	399	2.7862	0.6488	22.552	-7.942	0.0000001*

Values are significant (P<0.05).

The diversity of lepidopterans fluctuated with months such that May manifested the maximum diversity (H') 2.8053, followed by April (2.7123), June (2.4775), and March (2.4757). The highest t-test value was found for May and June comparison (4.9387) showing significant differences in the result. All the results were significant P<0.05 (Table 4).

Identification of the Sampled Lepidopteran Population

Identification characters of the sampled 29 species are as follows:

Amata phegea

Dusky blue wings; each forewing possesses six white spots and the hind wing has two or three white patches.

Black thread-like antennae with white tip and the 6th abdominal segment marked by a yellowish band (Figure 4: A).

Table 4. Shannon-Weiner diversity indices (H') demonstrating variation in Lepidopteran diversity in four months (March - June).

Months	N1	H'1	E1	N2	H'2	E2	Df	t-test	P-value
March vs April	404	2.4757	0.5945	641	2.7123	0.5195	992.61	-3.9325	0.00009*
March vs May	404	2.4757	0.5945	674	2.8053	0.5904	987.26	-5.602	0.00000*
March vs June	404	2.4757	0.5945	294	2.4775	0.6269	614.18	-0.02661	0.97878
April vs May	641	2.7123	0.5195	674	2.8053	0.5904	1308.4	-1.5771	0.11501
April vs June	641	2.7123	0.5195	294	2.4775	0.6269	675.56	3.476	0.00054*
May vs June	674	2.8053	0.5904	294	2.4775	0.6269	651.79	4.9387	0.000001*

Euproctis smilis

Fore wings are white but with few black markings in males and slight blotches in females on the tornus. The characteristic feature is the whitish abdomen with a yellow-orange abdominal tip. Males possess comb-like antennae (Figure 4: B).

Rhodometra sacraia

Both wings are light yellow but, the fore wings have a red tilted band while the hind wings lack a diagonal band. Thorax and head are soft yellow and the abdomen is pure white. The male has bipectinate antennae (Figure 4: C).

Pelopidas mathias

Wings are brown with black streaks on the upper side and pale underside. Both wings possess whitish spots. Each forewing contains eight spots; three near the apex and the other in the center. Antennae are hooked (Sidat and Bhatt, 2020) (Figure 4: D).

Chilades parrhasius

The upper surface of both wings is bluish-gray with dark edges whereas the lower side is brownish-grey. Both wings contain end cell bars. The hind wing possesses three dark spots on the wing base and two spots with orange boundaries on the tornus (Boruah et al., 2018) (Figure 4: E1, E2).

Tarucus nara

It is a small butterfly having wings 23 to 29 millimeters long. Fore wings are light brown on the top in females and light bluish-purple in males. Each hind wing is white, ovoid with conspicuous black stripes and borders below, and has a tail. Antennae are black and narrow with white spots (Kumar et al., 2012) (Figure 4: F1, F2).

Agrotis ipsilon

The body of the larvae is greyish brown to almost black on top and pale underneath. The head is brown with black marks and the epidermis is characterized by many black granules (Gibb, 2014) (Figure 4: G).

Zizeeria karsandra

Wings are pale brown having some dark blue tinge on top and greyish below. The underside of the fore wings has characteristic spherical marks in the center of the cell, a small oblique line below it, and a chain of 8 curved black discal spots. The lower side of the hind wings has a series of black blotches with white boundaries (Harinath et al., 2015; Talbot, 1978) (Figure 4: H1, H2).

Helicoverpa armigera

The adult is brown-yellow and heavy-bodied. Fore wings are yellow-brown, containing a chain of small black dots on the termen and a dark reniform mark in the mid. Hind wings are creamy to dull yellow with dark margins (Wubneh, 2016; Hamza et al., 2020) (Figure 4: I).

Mythimna separate

The larval head is brownish with reticulation exhibiting a prominent inverted 'Y'. Larvae are of various colors. The body is covered with longitudinal bands of white surrounded by broad brown-black lines on the sides of the body (Tara and Hussain, 2019) (Figure 4: J).

Mamestra brassicae

A mature larva is light green or pinkish grey. Spiracles are white and ovoid with dark peritreme (Sannino and Espinosa, 1999) (Figure 4: K).

Spodoptera litura

The larval body is green or brownish, the head is brown having reticulation sideways and a 'Y' marking on the head shield. Black specks present noticeably on the 1st and 8th segments of the abdomen while the 2nd and 3rd thoracic segments contain yellow spots. An obvious orange or yellow stripe is dorsally present and the spiracular band is pinkish orange or yellow (Bragard et al., 2019) (Figure 4: L).

Spodoptera exigua

The larval body is of variable shades; mature larvae are greenish dorsally with a yellow or pink shade on the underside. 'Y' marking is present on the head, skin is plane with dashes or chains of dark patches on the dorsolateral and upper surface. A lateral white band is present on the sides of the body with white spiracles having a black periphery (Passoa, 1991) (Figure 4: M).

Trichoplusia ni

A full-grown larva is chiefly green with a lateral white line over the spiracles. Two slender fade white straps are present dorsally. The head case is light green, the body is widened on the back, and the front is slender (Capinera, 2002a; Talhouk, 2002) (Figure 4: N).

Vanessa cardui

Both wings are striking orange, and black with white marks on the top while the underside is grey, brown, and blackish. Fore wings have black scales with white dots on the apex. Each hind wing possesses a series of 4 eye spots and the outer margin displays a chain of 5 pitch black dots (Hodgson et al., 2021) (Figure 4: O).

Ariadne merione**Adults**

Reddish-brown or orange-brown wings with dark zigzag lines. Fore wings contain a white spot near the apex (Bala et al., 2014) (Figure 5: A1).

Larvae

Willow and green, possess a pair of furcated spines on the head, a yellow longitudinal stripe on the dorsal side, and two lines of small spines present on the sides and back of the larva (Talbot, 1978) (Figure 5: A2, A3).

Danaus chrysippus

Wings are 7 to 8cm long; orange-brown; brighter on the top side. Fore wings have a black apex and chalky specks at the outer edges. Hind wings have narrow dark margins with a chain of small white dots; females exhibit 3 conspicuous black marks in the mid (while males have four spots) (Mangi et al., 2023; Sidat and Bhatt, 2020; Perveen and Fazal, 2013) (Figure 5: B).

Colias croceus

Wings are 46- 54 mm in length and have orange-yellowish with wide black-brown margins. Fore wings have a conspicuous black splotch in the middle; underneath is lighter with a green shade having a dark central spot with a light center. Females are recognized by prominent yellow marks on the dark brown edges of the upper sides of the wings. Hind wings possess a white central spot with a reddish faint boundary (Ali and Shrivastava, 2021; Attaullah et al., 2018) (Figure 5: C1, C2).

Belenois aurota

Wings are cream-colored upside, and white with a yellowish tinge underneath. The fore wing upper side contains a small black stipe in the discal region, 5 acne at the apex, and the terminal edge of the dorsum. The hind wing contains a black border on the topside amalgamated with a chain of sub-marginal black markings, a dark dot present on the edge of the Sc+R₁ vein (Haroon, 2016; Ge et al., 2021) (Figure 5: D).

Catopsilia pomona**Male**

Both wings are white with a prominent yellow shade that becomes light near the borders. Apex is black on fore wing while hind wings lack marginal markings (Abro et al., 2018) (Figure 5: E1).

Females

Fore wings have tips with dark costa; a circular black patch in the discal area and a dusky strap broadened near the tip. Hind wings possess dark marginal boundaries (Talbot, 1978) (Figure 5: E2).

Colias erate

Both wings are yellow. Fore wings have broad jet-black borders with a black splotch on the top side while Hind wings contain a faint beige blotch and contain small marginal black spots (Attaullah et al., 2018) (Figure 6: A).

Eurema hecabe

It has intense yellow wings; the upper side of the fore wing has wide apical brownish-black margins while the hind wing has dark edges. The underside of both wings is soft yellowish with thin black edges and brown spots (Mangi et al., 2023; Haroon, 2016; Sidat and Bhatt, 2020) (Figure 6: B).

Pieris canidia

Fore wings are dull creamy upside, margin, and costa have dispersed blackish scales and a circular black mark in

interspace 3; the underside is cream colored; apex is yellow with dark scales and 3 obvious dark spots present. Hind wings contain 4 or 5 dark spots terminally on apices; a large prominent black spot on top and underside is densely dusted with black scales (Mangi et al., 2023; Ali and Shrivastava, 2021; Talbot, 1978) (Figure 6: C).

Pieris brassicae

Male

Fore wings are creamy white on the upper side with no obvious black spots and black scales on the margins, while the underside is white, dusted with black scales, and contains two prominent black spots. The upper side of the hind wings is blotched with black scales; a big subcostal black speck is present, whereas the underside is slightly ochraceous brown stippled with small black scales and the subcostal black spot showing through the upside present ahead of the apex (Talbot, 1978) (Figure 6: D1).

Female

Larger than males. The upper forewing is similar to males, but the black scales on the base are relatively more outstretched and contain two conspicuous black spots. The wings are light yellow sprinkled with grey underneath (Attaullah et al., 2018) (Figure 6: D2).

Larvae

Mature instar possesses twelve body segments with remarkable black spots, a rounded head, and a few small hairs on a dark green-yellow body (Ahmad et al. 2007) (Figure 6: D3).

Pontia daplidice

Male

Fore wings are chalky with pitch-black scales and white specks on the apex; the cell of the upper surface contains a large black spot and the lower side has green spots in white. Hind wings have white upper sides with underneath spots seeing through them and are dusted with green underneath (Bora et al., 2020) (Figure 6: E1).

Female

Almost like males with few differences; fore wings have extended black scales at the apex and discoidal blotch on the upper side. Hind wings have characteristic two series of terminal dark marks on the upper side while the underside is checkered green with broader markings on the creamy background (Bora et al., 2020) (Figure 6: E2).

Papilio demoleus

Larval stages

The 1st instar is oblong, pale brown, or dark brown with a white blotch on the top side (Figure 6: F1). The fourth instar is black with a white strap on the thorax (Figure 6: F2). The 5th instar (mature larva) possesses a greenish tinge with a light green head, on the 2nd segment of the thorax two marks resembling eyes are present and a barb-like part is present dorsally on the last segment (Mangi et al., 2023; Jahnavi et al., 2018) (Figure 6: F3).

Adult

Both wings are black containing yellowish spots on the margin and yellow streaks on the underside. The abdomen is dorsally black and ventrally yellow (Jahnavi et al., 2018) (Figure 6: F4).

Ostrinia nubilalis

Larval instars are pink-grey or fade brownish on the dorsal side. The head case is brown to blackish with yellow-brown plates on the thorax. On each segment, circular dark dots are present (Capinera, 2002b) (Figure 6: G).

Argus convolvuli

The body is anteriorly broader and posteriorly pointed, and the head and thorax are greyish-white with two brown specks present laterally on the thorax. The abdomen is dull grey having interchanging pink and black marks on the lateral sides. Fore wings are slender and extended possessing intense buff-colored scales while hind wings are comparatively smaller with brownish-blond scales (Aljaf, 2020) (Figure 6: H).

Macroglossum belis

The head, thorax, and abdomen are reddish brown; light yellow spots are found laterally on the abdomen. The fore wings are red-brown having a rotund exterior edge and the hind wings display a yellowish-red middle region and a redder brown termen (Gurule, 2013) (Figure 6: I).

The present study was designed to identify species and estimate the relative abundance and species diversity of the order Lepidoptera from the agro-ecosystems of Sialkot district. A total of 2013 specimens constituting 29 species were collected from four crops (fodder, brassica, wheat, and vegetables) in four tehsils of district Sialkot. The 10 recorded

families were Noctuidae, Pieridea, Lycaenidae, Geometridae, Nymphalidae, Hesperidae, Erebidae, Spingidae, Papilionidae, and Pyralidae. Family-wise investigation revealed that the family Pieridae represented the highest relative



(A) *Amata phegea*



(B) *Euproctis smilis*



(C) *Rhodometra sacraria*



(D) *Pelopidas mathias*



(E1) *Chilades parrhasius* Upside



(E2) *C. parrhasius* Underside



(F1) *Tarucus nara* upside



(F2) *T. nara* lower side



(G) Larva of *Agrotis ipsilon*



(H1) *Zizeeria karsandra* upside



(H2) *Zizeeria karsandra* lower side



(I) *Helicoverpa armigera*



(J) Larva of *Mythimna separata*



(L) Larva of *Spodoptera exigua*

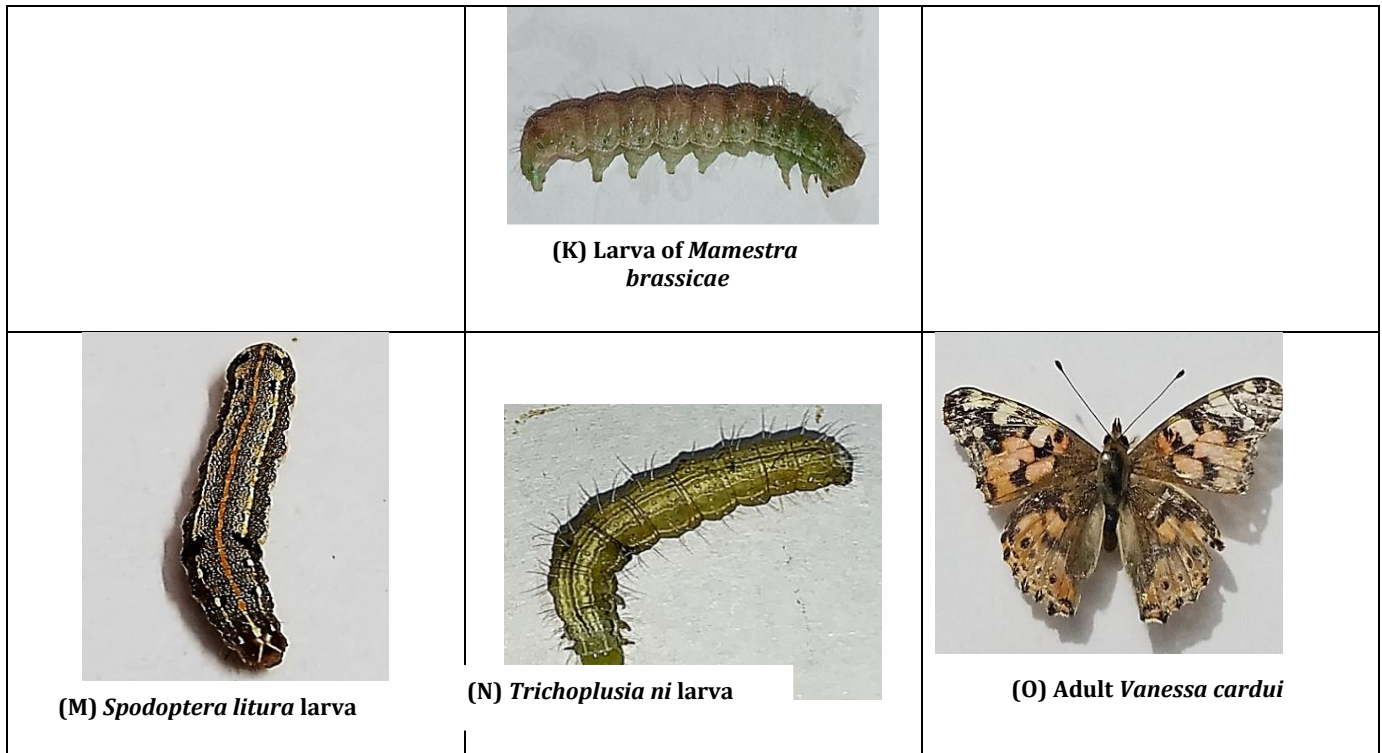
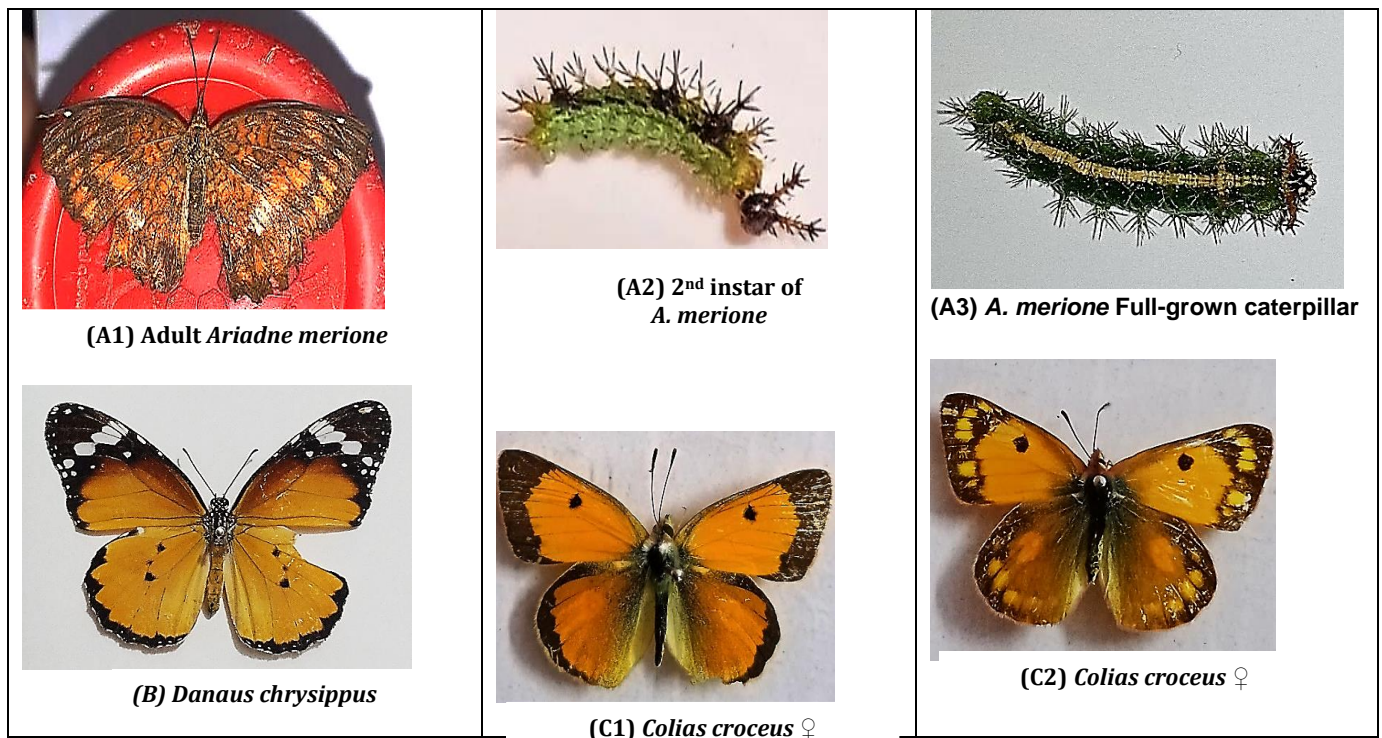


Figure 4. Lepidopteran representatives shown from *Amata phegea* to *Vanessa cardui*.



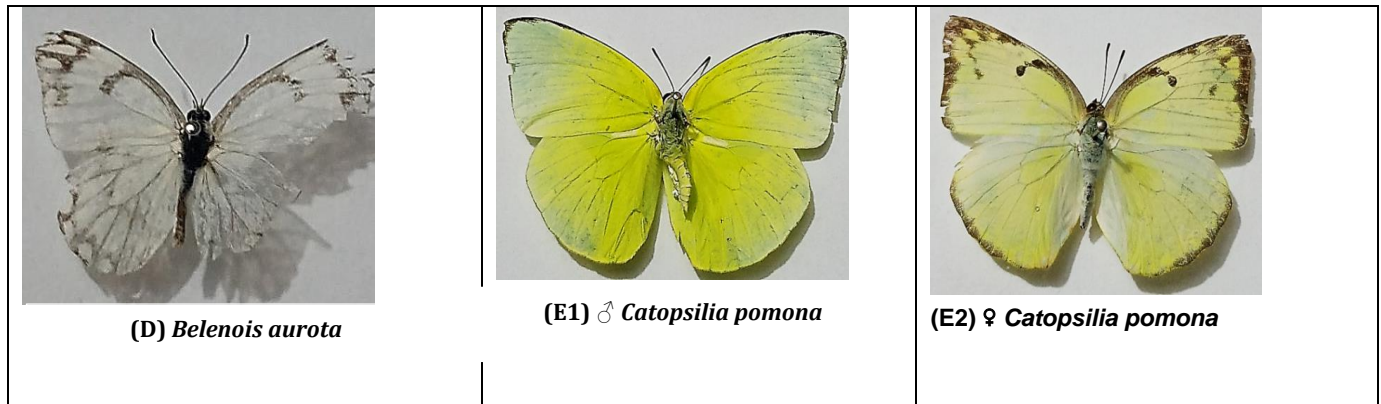
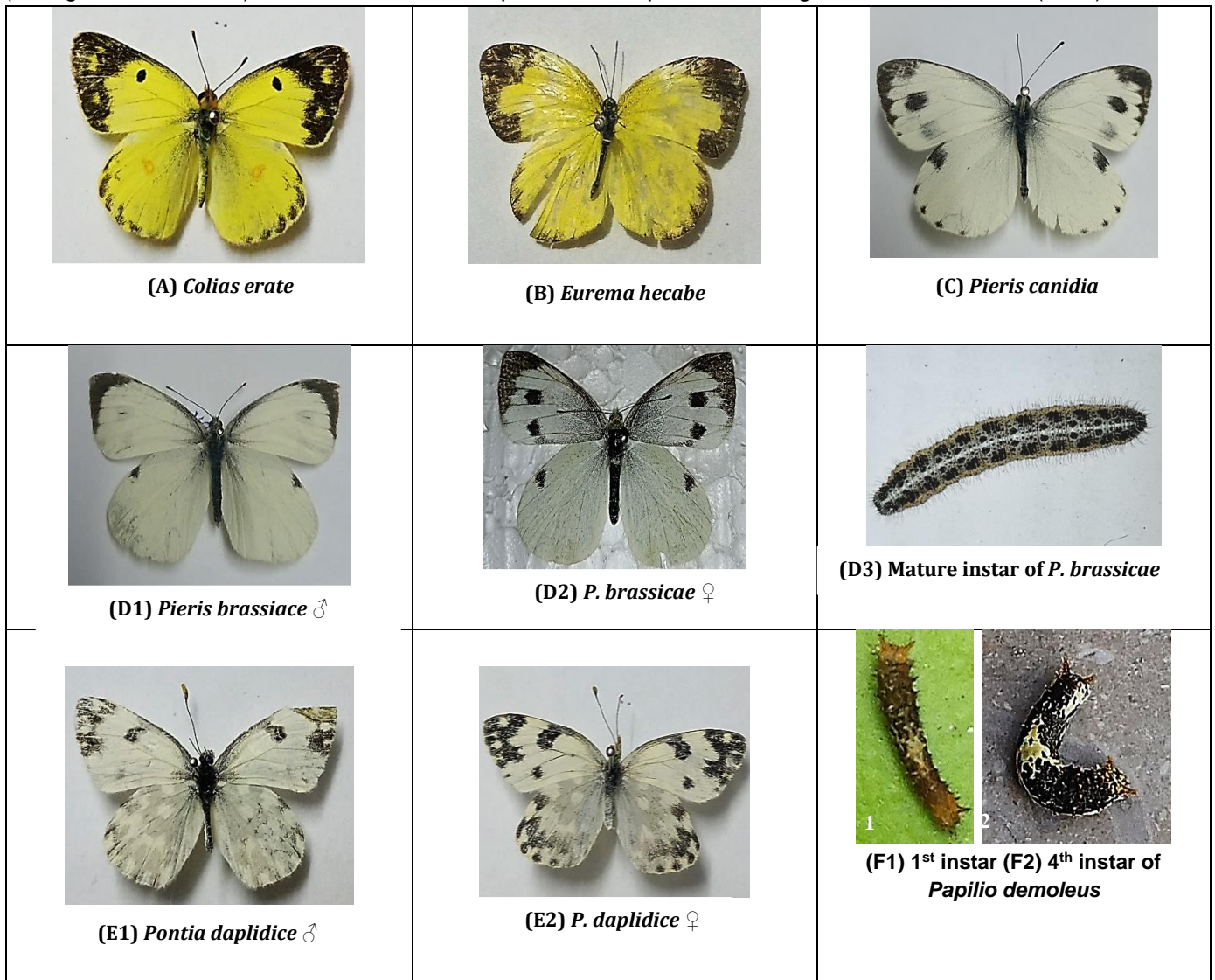


Figure 5. Lepidopteran representatives shown from *Ariadne merione* to *Catopsilia pomona*.

abundance (41.03%). This maximum abundance of Pieridae may be correlated to the presence of suitable host plants (Murugesan et al. 2013). The current result was parallel to the previous findings of Rani and Ahmed (2021); Usman



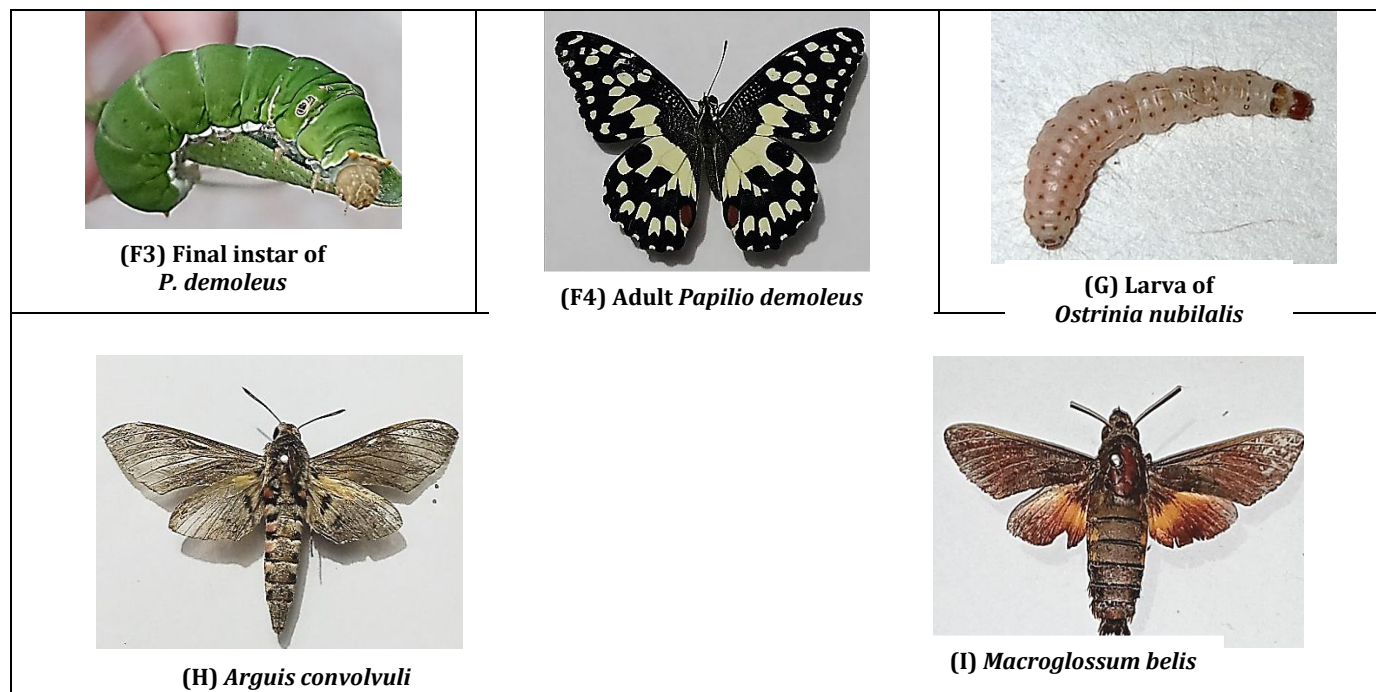


Figure 6. Lepidopteran representatives shown from *Colias erate* to *Macroglossum belis*.

et al. (2017); Abro et al. (2018); Iqbal et al. (2019 and Perveen and Ahmad (2012). Khan et al. (2014) and Kanimozhi et al. (2020) also reported that Pieridae was the dominant family. All these studies are analogous to the present findings. The richness and diversity of butterfly fauna is the indication of the health of a biome (Manzoor et al., 2013). The present study revealed that the second abundant family was Noctuidae with a relative abundance of 39.29%. Maalik et al. (2022) also documented Noctuidae as a diverse family. Thakur et al. (2013) recognized that Noctuid species are serious pests of vegetables and crops. Soomro et al., (2021) also observed the diversity of noctuid moths from Khairpur Mir. Mangi et al. (2023) reported 03 families: Pieridae, Papilionidae and Nymphalidae with 06 genera and 06 species: *Danaus chrysippus* (Linnaeus,1758), *Vanessa cardui* (Linnaeus,1758), *Junonia almana* (Linnaeus,1758), *Papilio demoleus* Linnaeus,1758, *Eurema hecabe* (Linnaeus,1758) and *Pieris canidia* (Sparman, 1768) from Larkana district of Sindh Province of Pakistan.

The crop-wise analysis demonstrated that the highest relative abundance of Lepidopterans was found in fodder (53.40%) and was analogous to the findings of Maalik et al. (2013). In the present study, the dominant species from all the crops and localities was *H. armigera* (17.44%) and *P. brassicae* (11.87%) was the second abundant species while *D. chrysippus* was the least abundant species (0.25%). The highest abundance of *H. armigera* is due to its polyphagous nature making it a devastating pest of cotton, tomato, maize, sorghum, berseem, and many other commercially important crops (Tembrock et al., 2019). The lowest abundance of *D. chrysippus* in the study area indicated that sampling duration, host plantation, and environmental conditions of the study area were not very favorable for this species (Narmadha et al., 2023).

Shannon diversity analysis was performed to check the variations in the diversity of the collected species. Community stability is enhanced by a higher diversity of species because of improved usage of space, and interactions of different species (Donohue et al., 2013; Isbell et al., 2009). Crop-wise Shannon indices were applied (Table 5) that showed that maximum diversity ($H' = 2.999$) was found in fodder ($N = 1075$) followed by vegetable ($H' = 2.7862$, $N = 399$), brassica ($H' = 2.2908$, $N = 521$) and minimum diversity index ($H' = 1.692$) was calculated for wheat ($N = 18$). Amber et al. (2015) also reported the highest Lepidopteran species in fodder crop ($H' = 1.735$). Significant results were found in all the crops. This showed that the study area has a rich diversity of lepidopteran fauna. Fluctuations in diversity and abundance were observed in different months during the study. Maximum abundance was found in May (33.48%) and lowest in June (14.61%). A comparable result was reported by Ghani and Maalik (2020) who also observed the least relative abundance of insect fauna in June collected from wheat crops from Sialkot, Pakistan. From the calculated month-wise diversity, it was found that the highest Shannon index was estimated in May ($H' = 2.8053$) followed by 2.7123 in April, $H' = 2.4775$ in June, and 2.4775 in March. This indicates that May and April were favorable months for the Lepidopteran community. The distribution of pests is influenced by atmospheric temperature (Macfadyen and Kriticos, 2012). Hence,

species number and diversity decrease in warm environmental conditions and rise in moderate ones (Mcglynn et al., 2019). The study was conducted to explore the abundance and diversity of Lepidopteran species in agro-ecosystems of district Sialkot, Pakistan. Rich Lepidopteran diversity was documented from the sampled area. In this research 29 species belonging to 10 families were recorded. The maximum relative abundance of the Lepidopteran population was found in fodder and lowest in wheat. Family Pieridae was the most prevalent and species-rich family followed by the Noctuidae family. *H. armigera* was the most dominant and diverse species due to its polyphagous nature. The month of May was the peak month for the Lepidopteran population due to the ample availability of host plants. Lepidopteran diversity and abundance are strongly influenced by vegetation and climate. Consequently, species diversity and abundance are high in areas with a high concentration of plantations. The ecological circumstances of the Sialkot district are favorable to the diversity and abundance of the order Lepidoptera, according to the current study's findings. Programs for conservation and monitoring in the future will benefit from this kind of research.

CONCLUSION

Current study concluded that ecological conditions of district Sialkot are favorable for diversity and abundance of order Lepidoptera. Diversity and abundance of insect species depend on flora. Vegetation dense regions are rich in species diversity and abundance. This kind of study is beneficial for efficient monitoring of insect's species diversity.

AUTHOR'S CONTRIBUTION

Sadia Maalik performed conceptualization, supervision and formal analysis, Nehal Khalid wrote the manuscript and performed methodology, Sajida Mushtaq supervised and analyzed the software. Moazama Batool performed the role of visualization and conceptualization, Ayesha Hafeez reviewed and edited the manuscript. Nazia Ehsan analyzed the data and made interpretations, Naheed bano revised the scientific content of manuscript.

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AVAILABILITY OF DATA AND MATERIAL

All data underlying the results are available as part of the article and no additional source data is required.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

CONSENT FOR PUBLICATION

All authors are willing to publish the data.

CONFLICT OF INTERESTS

All authors declare that there is no conflict of interest in present study.

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