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Diversity and relative abundance of arthropods on peach under northwestern region of Punjab, India

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Abstract
Arthropods play very crucial roles in maintaining productive and healthy orchard ecosystem. The diverse fauna of arthropods which inhibit the ecosystem of peach orchard include pests, natural enemies and pollinators. In our study, we assessed the biodiversity and abundance of arthropods visitors in peach orchard. Different methods including sweep nets, visual searching methods, yellow sticky traps and pheromone traps at fortnight interval resulted in a total of twenty species of arthropods collection. Among them, pollinators including eight species constituted a large proportion of arthropods followed by four species of each group *viz.* arachnids, insect-pests and natural enemies. Among pollinators apidae family showed maximum relative abundance (82%) followed by syrphidae (10%) and halicitdae (8%). The relative abundance was highest in *Apis mellifera* (21.74%) followed by *A. cerana* (17.36%) and lowest relative abundance was observed in *Xylocopa fenestrata* (6.85%). All the pollinator species were most active at 1200h of the day in comparison to 1600h and 0800h. In case of pests, *Myzus persicae* (47.11%) was the most abundant insect while among arachnids *Tetranychus urticae* (7.81%) was the most prominent mite that attacks the peach trees. Among natural enemies, *Coccinella septumpunctata* (7.98%) was the most dominant insect. Maximum mean abundance of all the pests and natural enemies were observed during the months of April to June and that of pollinators were observed during peak flowering season February-March. Our data on abundance and diversity of arthropods will help in efficient management of pests without causing considerable damage to beneficial insects.

Keywords: Abundance, diversity, natural enemies, peach, pests, pollinators

1. Introduction
Peach *Prunus persica* (L.) Batsch, is the economically crucial fruit belonged to Rosaceae family and is cultivated in temperate regions (Abidi *et al.*, 2018) [1]. The peach is a sweet, juicy fruit known for its distinct color and taste. It is rich in vitamins, minerals, antioxidant and low in calories. It can also help improve cholesterol levels and may reduce risk of developing heart disease (Sachdev, 2022) [2]. Peach flowers produce abundant nectar and pollen and are attractive to many pollinating agents. Though they are self-compatible, yet cross pollination helps in improving the quality and increasing the yield of the crop (Abrol, 2005) [3]. Insect pollinators play vital role in pollination of peach and the strong effect of insect pollinator diversity on the degree of pollination may be a result of complementary behavior of the various functional groups, their richness and abundance. Insects belonging to apidae family including honey bees and *Xylocopa* sp. regarded as the most important and dominant commercial pollinators (<90 per cent), although other bee species like alkali bees (Nomia), leafcutter bees (Megachilidae) and bumble bees (Bombus) also helps in pollination (Dar *et al.*, 2020) [4]. Despite the pollinators, there are huge diversity of insect-pests and mites found on peach trees, causing damage to the bloom, fruits, twigs, limbs, and trunk. The most prevalent insect-pests reported are Peach leaf curl aphid, Peach black aphid, Green peach aphid, Chaffer and other defoliating beetles, Hairy caterpillars, Leafhoppers, Oriental fruit moth, Peach fruit fly, Peach flat headed borer and Plum caseworm (Stocks and Olmstead, 2013) [5]. Among pests belonging to Arachnida class, Two-spotted spider mites and Oriental spider mites, are reported to cause infestation on peach trees (LaForest, 2008) [6]. The natural enemies are essential agents in balancing the pest population including ladybird beetle, hoverflies and green lacewings are reported in peach orchard (Gacem and Mezerdi, 2022) [7]. However, little is known about the arthropod fauna on peach orchards in Punjab. Knowledge about the pollinator's abundance, pests and natural enemies would be helpful in pest forecasting and utilization of their management practices without disturbing beneficial insects. Therefore, the present study aimed to identify the biodiversity and seasonal abundance of the arthropods

community including pollinators, pests and natural enemies on peach orchards.

2. Materials and methods

2.1 Survey and collection

The samples of arthropods visiting peach were collected from orchard present at Khalsa College Amritsar, located at 31.63°N 74.87°E with an average elevation of 234 meters (768 ft) during February to October 2022.

2.2 Climatic characteristics

Amritsar has a semiarid climate, typical of Northwestern India. This region experiences four seasons primarily: winter season (December to March), summer season (April to June), monsoon season (July to September) and post-monsoon season (October to November). Annual rainfall is about 703.4 millimeters (27.7 inches).

2.3 Method of collection for pollinators

The collections of pollinators were carried out with the help of insect collection net (32 cm diameters) with adjustable hand which allowed relatively easy access to foragers from a distance of 2.5 m. Thirty sweeps of insect collections net were made at three- hour intervals starting from 0800 to 1600h, over every week during the blooming period of crop. The collected samples were later sorted in Entomology Lab, P.G. Department of Agriculture, Khalsa College, Amritsar for subsequent identification, grouping and observations.

2.4 Method of collection for pests and natural enemies

Collection of pests and natural enemies were done during morning hours from 10.00 am to 11.00 am from five plants, which were selected randomly. From each plant 15 leaves were collected from the different part of tree canopy i.e. lower, middle and upper canopy. The samples were collected using sweep nets, traps and manually. Trapped insects were killed using ethyl acetate in the killing bottle before being identified and preserved. The specimens were stretched, dried, dry pinned (for hard bodied insects) and preserved in the 70% ethyl alcohol (for soft bodied insects). Different traps used to collect pests and natural enemies' population were as follows:

2.4.1 Yellow sticky traps

The yellow sticky trap was made of art paper (15 × 20 cm) which was painted with lemon yellow colour on both sides, sealed with a thin transparent plastic cover, and smeared with sticky glue. Installations of five yellow sticky traps were done at five randomly selected trees. Reinstallation of traps was taken once the traps were full of insects or dust. In our study, yellow sticky traps were used to determine the abundance of aphids and spiders.

2.4.2 Pheromone traps

Installations of sixteen pheromone traps per acre were done at randomly selected trees. The traps were made from yellow buckets with white lids and were filled with para-pheromones i.e., methyl eugenol and insecticides which attracts and kill the male fruit flies.

2.5 Abundance of arthropods

Relative abundance of various arthropods was calculated by using formula

$$\textbf{Relative Abundance (\%)} = \frac{\textbf{Total number of each species}}{\textbf{Total number of all species}} \times \mathbf{100}$$

The data on various aspects was statistically analyzed with the help of online software ICAR WASP through Randomized block design using analysis of variance (ANOVA) and were separated by least significant difference (LSD) at p= 0.05 (Gomez and Gomez, 1984) [8].

2.6 Diversity Indices

The diversity indices of arthropods were analyzed by using seven diversity indices comprising one evenness indices [Shannon evenness/Pielou evenness, 1966 (E of H')]; five proportional abundance indices [Simpson's index, D; Simpson's index of diversity, S; Simpson's reciprocal index 1/D(S); Shannon index of diversity, 1949 (H'); and Berger-Parker's index, d]; one species number indices [Marglef's Index, 1958 (D_{Mg}) (Table1).

Table 1: Measures of species diversity

Name of the diversity measure	Symbol	Formula*
Species evenness indices		
Shannon evenness/ Pielou evenness	E	H'/*ln*(S)
Proportional abundance indices		
Simpson's index	D	∑(n/N)2
Simpson's index of diversity	S	1-D
Simpson's reciprocal index	1/D(S) or *1/Ds*	$1/\sum p_i^2$
Shannon index of diversity	H'	-∑(pi× *ln*pi
Berger- Parker index	d	N_{max}/N
Species number indices		
Margalef's index (1958)	D(Mg) or D_{Mg}	(S-1)/ *ln*N

*Definition of symbols: S, the number of species in the sample; p_i, the proportion of individuals in the i_{th} species (p_i = ni/N); n_i, is the number of individuals of species *i* in the sample; N, the total number of individuals sampled; $N_{max,}$ the number of individuals of the most abundant species.

3. Results and Discussions

3.1 Abundance of arthropods visiting peach orchard

Total twenty species of arthropod community were collected from the peach orchard namely Predatory mite, *Euseius finlandicus* (Gupta), Two-spotted spider mite, *Tetranychus urticae* (Koch), Black footed yellow sac spider, *Cheiracanthium inclusum* (Hentz), Jumping spider, *Pelegrina exigua* (Banks), Painted bug, *Bagrada hilaris* (Burmeister), Green stink bug, *Chinavia hilaris* (Say), Green peach aphid, *Myzus persicae* (Sulzer), Blue banded bee, *Amegilla cingulata*

(Fabricius), Rock bee, *Apis dorsata* (F.), Indian hive bee, *Apis cerana* (F.), Little bee, *Apis florea* (F.), European bee, *Apis mellifera* (Linnaeus), Carpenter bee, *Xylocopa fenestrata* (F.), Black carpenter ant, *Camponotus pennsylvanicus* (Dee Geer), Sweat bee, *Lasioglossum* sp., Peach fruit fly, *Bactrocera zonata* (Hendel), Syrphid fly, *Eristalinus megacephalus* (Rossi), Dragonfly, *Anax imperator* (Leach), Lady bird bettle, *Coccinella septumpunctata* L., and Parthenium beetle, *Zygogramma bicolorata* (Pallister) (Table 2).

3.1.1 Pollinators

A total of eight pollinators were collected from peach orchard which are belonging to two orders (hymenoptera and dipetra) and three families (apidae, syrphidae and halicitidae) of class Insecta. It was observed that 82 per cent pollinators were belonging to family apidae followed by syrphidae (10%) and halicitidae (8%). All the four species of honey bees were most abundant insect pollinators belonging to apidae family which comprised 60 per cent of total flower visitation. The per cent relative abundance of different pollinators on peach indicated that *A. mellifera* (21.74%) was the most prevalent pollinator followed by *A. cerana (*17.36%) while the *X. fenestrata* (6.85%) was the least visitor (Fig 1).

The mean population of pollinators was highest in *A. mellifera* (6.34±0.62 bees/30 sweeps) whereas, the lowest was reported in *X. fenestrata* (2.00±1.48 bees/30 sweeps). Time wise, the mean populations of pollinators per 30 sweeps revealed that the eight pollinator species were significantly higher at 1200h (34.36±5.02) followed by at 1600h (28.20±4.60) and the lowest population at 0800h (24.83±4.34) (Table 3). The present investigation on pollinator abundance is in confirmity with the findings of Kumar (1995) [9] who reported that *A. cerana* and *A. mellifera* were the most abundant insect pollinator on peach crop. He also reported that different insect visitors belong to order hymenoptera, diptera, lepidoptera and coleoptera. Choi and Kim (1988) [10] also reported that honey bees constituted 70-80 per cent of total insect population on peach bloom in North Korea. Abrol *et al.* (1989) [11] also studied the pollinators on different temperate fruit crops such as apple, peach, plum and cherry in Jammu and Kashmir. The important pollinators visiting these crops were *Xylocopa* sp., *Lasioglossum* sp., *Halictus* sp., *A. mellifera* and *Bombus terrestris.* Hourly activity duration of pollinators has a direct bearing on the intensity of pollination. Pollinators will pollinate more flowers if they remain active for a longer duration. Foraging activity duration of a pollinator varies from species to species and plant to plant (Free, 1993) [12]. During the present studies the time wise, the pollinator abundance and hourly activity pattern on peach flower.

Table 2: Arthropods visiting peach orchard during 2022

Class	Order	Family	Scientific name	Common name
Arachnida	Mesostigmata	Phytoseiidae	*Euseius finlandicus*	Predatory mite
	Trombidiformes	Tetranychidae	*Tetranychus urticae*	Two-spotted spider mite
	Araneae	Cheiracanthiidae	*Cheiracanthium inclusum*	Black footed yellow sac spider
		Salticidae	*Pelegrina exigua*	Jumping spider
Insecta	Hemiptera	Pentatomidae	*Bagrada hilaris*	Painted bug
			Chinavia hilaris	Green stink bug
		Aphididae	*Myzus persicae*	Green peach aphid
	Hymenoptera	Apidae	*Amegilla cingulata*	Blue banded bee
			Apis dorsata	Rock bee
			Apis cerana	Indian hive bee
			Apis florea	Little bee
			Apis mellifera	European bee
			Xylocopa fenestrata	Carpenter bee
		Formicinae	*Camponotus pennsylvanicus*	Black carpenter ant
		Halicitidae	*Lasioglossum sp.*	Sweat bee
	Diptera	Tephritidae	*Bactrocera zonata*	Peach fruit fly
		Syrphidae	*Eristalinus megacephalus*	Syrphid fly
	Odonata	Aeshnidae	*Anax imperator*	Dragonfly
	Coleoptera	Coccinellidae	*Coccinella septempunctata*	Lady bird bettle
		Chrysomelidae	*Zygogramma bicolorata*	Parthenium beetle

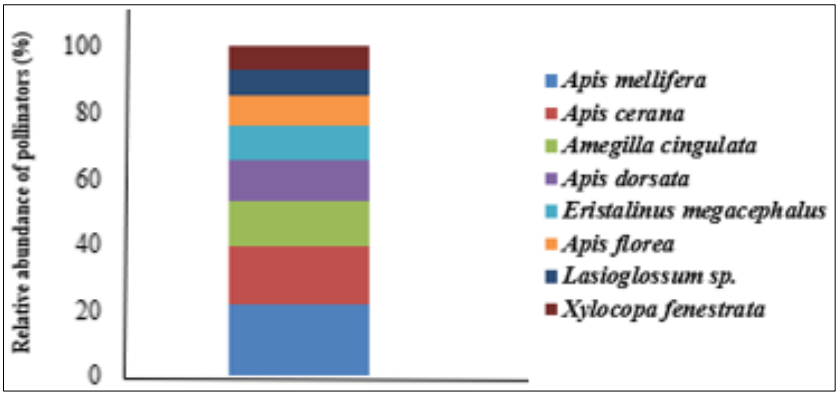

Fig 1: Per cent relative abundance of pollinators visiting peach orchard

Table 3: Relative abundance of pollinators visiting peach orchard

Time Pollinators	*Mean number of pollinators per 30 net sweeps			Overall Mean
	0800h	1200h	1600h	
Apis mellifera	5.63^{a}±0.51	7.56^{a}±0.73	5.83^{a}±0.63	6.34±0.62
Apis cerana	4.36^{ab}±0.59	5.86^{b}±0.74	4.96^{ab}±0.62	5.06±0.65
Amegilla cingulata	3.30^{bc}±0.54	4.73^{bc}±0.84	4.23^{abc}±0.65	4.08±0.68
Apis dorsata	2.96^{bc}±0.57	4.36^{bc}±0.62	3.73^{bcd}±0.58	3.68±0.59
Eristalinus megacephalus	2.56^{c}±0.52	3.30^{cd}±0.58	2.96^{cd}±0.45	2.94±0.51
Apis florea	2.16^{c}±0.56	3.26^{cd}±0.48	2.70^{bcd}±0.55	2.71±0.53
Lasioglossum sp.	2.06^{c}±0.48	2.76^{cd}±0.60	2.16^{cd}±0.57	2.33±0.55
Xylocopa fenestrata	1.80^{c}±0.52	2.56^{d}±0.39	1.63^{d}±0.52	2.00±1.48
Total	24.83±4.34	34.36±5.02	28.20±4.60	28.60±4.65
LSD (p =0.05)	1.72	2.22	2.24	6.18

*Mean±S.E; Mean of five replications, LSD; Least significant difference, variables (a, b, c....) significantly at 5% level of significance.

start rising from early in the morning hours (sunrise) and become peak maximum at midday (1200 hours) due to the presence of abundant pollen and nectar and declined at noon (1600 hours) due to the less availability of floral rewards and effect of environmental factors, *viz*. temperature and relative humidity. Roy *et al.* (2014) [13] also concluded the same results as maximum abundance of pollinators were at the middle of the day i.e., 12 noon. Apart from honey bees (hymenopterans) peach flowers were also visited by certain dipteran species. Similar observations were also reported by Arya and Badoni (2019) [14].

3.1.2 Pests and natural enemies

The per cent relative abundance of pest was higher in *M. persicae* (47.11%) and lowest of pest *B. hilaris* (0.95%) was observed (Fig 2). In case of natural enemies, the per cent relative abundance was found maximum in *C. septumpunctata* (7.98%) and least in *C. inclusum* (1.36) (Fig 3).

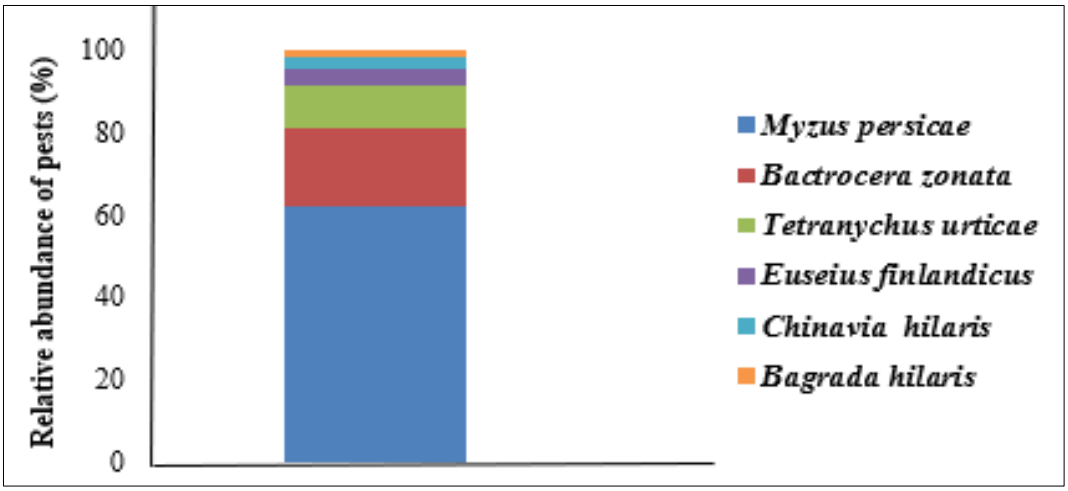

Fig 2: Per cent relative abundance of pests visiting peach orchard

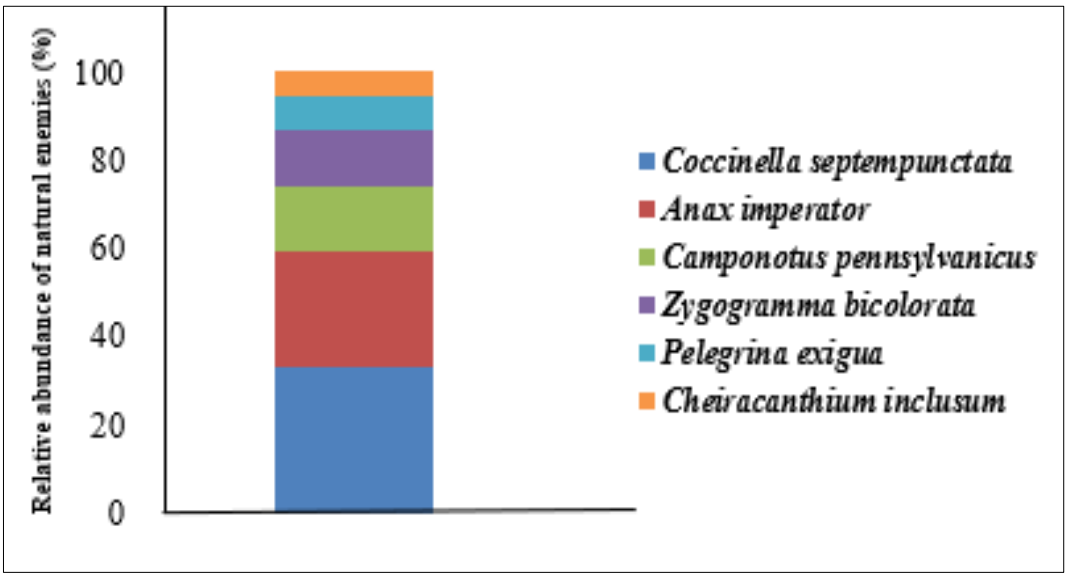

Fig 3: Per cent relative abundance of natural enemies visiting peach orchard

The maximum mean population of pests and natural enemies were recorded highest during the months of April to July due to the hot and summer season. In case of pests, the highest mean population of *M. persicae* (17.46±1.78) and the lowest of *B. hilaris* (0.31±0.13) was observed (Table 4). The maximum mean population was found of *M. persicae* during 1st fortnight of April. The population of *B. zonata* was maximum during 2nd fortnight of May. The maximum mean population of *T. urticae* was obtained during 2nd fortnight of May. The *E. finlandicus* had maximum population during 2nd fortnight of May. *C. hilaris* had maximum population in the 1st fortnight of May. In case of *B. hilaris* maximum mean population was observed in the 1st fortnight of June. The pest population was declining in month of August and remains inactive during 1st and 2nd fortnight of October. In case of natural enemies, the maximum mean population of *C. septumpunctata* (2.98±0.65) was highest and lowest of *C. inclusum* (0.44±0.23) was recorded (Table 5).

Table 4: Relative abundance of pests visiting peach orchard

Time / Pests	*Mean number of pests per 15 leaves																		Overall mean
	1st fortnight of Feb	2nd fortnight of Feb	1st fortnight of March	2nd fortnight of March	1st fortnight of April	2nd fortnight of April	1st fortnight of May	2nd fortnight of May	1st fortnight of June	2nd fortnight of June	1st fortnight of July	2nd fortnight of July	1st fortnight of August	2nd fortnight of August	1st fortnight of Sept	2nd fortnight of Sept	1st fortnight of Oct	2nd fortnight of Oct	
Myzus persicae	3.40^{a}±1.37	8.20^{a}±0.77	28.20^{a}±1.73	37.20^{a}±2.74	40.60^{a}±1.80	32.60^{a}±3.43	28.20^{a}±2.36	25.60^{a}±3.57	22.20^{a}±3.70	17.40^{a}±2.20	15.8^{a}±1.56	9.40^{a}±1.22	5.20^{a}±0.77	3.60^{a}±1.08	1.80^{a}±0.33	0.00^{b}±0.00	0.00^{b}±0.00	0.00^{b}±0.00	17.46±1.78
Bactrocera zonata	0.00^{b}±0.00	0.00^{b}±0.00	0.00^{b}±0.00	0.00^{b}±0.00	6.60^{b}±0.83	8.80^{b}±1.03	11.60^{b}±1.43	14.4^{b}±1.08	12.80^{b}±0.77	11.60^{b}±0.83	7.20^{b}±1.14	6.60^{b}±0.92	3.20^{ab}±0.77	2.80^{a}±0.59	0.00^{c}±0.00	0.00^{b}±0.00	0.00^{b}±0.00	0.00^{b}±0.00	4.75±0.52
Tetranychus urticae	0.00^{b}±0.00	0.00^{b}±0.00	1.40^{b}±0.45	1.60^{b}±0.45	2.00^{c}±0.62	3.80^{bc}±0.77	5.20^{c}±0.77	8.80^{c}±0.77	5.80^{c}±0.77	4.80^{c}±0.77	3.60^{c}±1.08	2.80^{c}±0.77	2.20^{bc}±0.77	1.80^{ab}±0.71	1.20^{ab}±0.52	0.80^{b}±0.33	0.00^{b}±0.00	0.00^{b}±0.00	2.54±0.53
Euseius finlandicus	0.00^{b}±0.00	0.00^{b}±0.00	0.00^{b}±0.00	0.40^{b}±0.21	0.20^{c}±0.17	1.20^{c}±0.52	3.00^{c}±0.63	4.20^{cd}±0.77	3.20^{c}±0.52	2.40^{cd}±0.45	2.20^{cd}±0.77	1.00^{cd}±0.40	1.00^{cd}±0.49	0.80^{b}±0.33	0.40^{bc}±0.21	0.20^{b}±0.17	0.00^{b}±0.00	0.00^{b}±0.00	1.12±0.31
Chinavia hilaris	0.00^{b}±0.00	0.00^{b}±0.00	0.00^{b}±0.00	0.00^{b}±0.00	0.60^{c}±0.35	2.20^{c}±0.52	3.00^{c}±0.63	2.80^{d}±0.59	2.20^{c}±0.77	1.80^{cd}±0.52	0.00^{d}±0.00	0.00^{d}±0.00	0.00^{d}±0.00	0.00^{b}±0.00	0.00^{c}±0.00	0.00^{b}±0.00	0.00^{b}±0.00	0.00^{b}±0.00	0.70±0.18
Bagrada hilaris	0.00^{b}±0.00	0.00^{b}±0.00	0.00^{b}±0.00	0.00^{b}±0.00	0.80^{c}±0.33	1.00^{c}±0.40	1.20^{c}±0.52	0.40^{d}±0.21	1.40^{c}±0.67	0.80^{d}±0.33	0.00^{d}±0.00	0.00^{d}±0.00	0.00^{d}±0.00	0.00^{b}±0.00	0.00^{c}±0.00	0.00^{b}±0.00	0.00^{b}±0.00	0.00^{b}±0.00	0.31±0.13
Total	3.40±1.37	8.20±0.77	29.60±2.18	39.20±3.40	50.80±4.10	49.60±6.67	52.20±6.34	56.20±6.92	47.60±7.20	38.80±5.10	28.80±4.55	19.80±3.31	11.60±2.80	9.00±2.71	3.40±1.06	1.00±0.50	0.00±0.00	0.00±0.00	26.88±3.45
LSD (p=0.05)	1.85	1.03	2.45	3.81	2.78	5.22	4.03	5.49	5.34	3.26	2.72	2.19	2.03	1.99	0.89	0.53	Non-significant	Non-significant	2.85

*Mean±S.E; Mean of five replications, LSD; Least significant difference, variables ($^{a, b, c..}$) significantly differ from each other at 5% level of significance

Table 5: Relative abundance of natural enemies visiting peach orchard

Time / Natural enemies	*Mean number of natural enemies per 15 leaves																		Overall mean
	1st fortnight of Feb	2nd fortnight of Feb	1st fortnight of March	2nd fortnight of March	1st fortnight of April	2nd fortnight of April	1st fortnight of May	2nd fortnight of May	1st fortnight of June	2nd fortnight of June	1st fortnight of July	2nd fortnight of July	1st fortnight of August	2nd fortnight of August	1st fortnight of Sept	2nd fortnight of Sept	1st fortnight of Oct	2nd fortnight of Oct	
Coccinella septempunctata	1.60a±1.49	1.20b±0.52	4.80a±0.77	7.20a±1.14	5.20a±0.95	5.00a±0.40	4.20a±0.77	4.00a±0.63	3.80a±0.77	3.60a±0.45	2.20ab±0.77	1.80b±0.77	1.40b±0.45	1.20b±0.33	0.60b±0.21	0.00b±0.00	0.00b±0.00	0.00b±0.00	2.98±0.65
Anax imperator	0.00b±0.00	0.00b±0.00	0.00c±0.00	0.00d±0.00	0.00c±0.00	0.00c±0.00	0.00b±0.00	0.00b±0.00	2.60ab±1.04	3.80a±1.45	4.20a±0.77	4.40a±0.83	6.20a±0.52	7.80a±1.03	4.20a±0.77	3.20a±0.77	2.20a±0.65	1.20a±0.43	2.21±0.46
Camponotus pennsylvanicus	0.00b±0.00	0.20b±0.40	1.80b±0.71	2.20bc±0.99	2.60b±0.83	2.00b±0.80	1.80b±0.82	1.80b±1.07	0.40bc±0.67	1.40ab±0.78	1.20b±0.52	1.20bc±0.71	1.00b±0.40	0.80b±0.35	0.80b±0.43	0.00b±0.00	0.80b±0.52	0.00b±0.00	1.27±0.62
Zygogramma bicolorata	0.40a±0.21	0.80ab±0.33	1.40bc±0.45	3.00b±0.63	2.60b±0.67	2.00b±0.63	1.40b±0.67	1.20b±0.33	1.80abc±0.71	0.80b±0.33	0.60b±0.35	0.20c±0.17	1.00b±0.40	0.60b±0.35	0.20b±0.17	0.00b±0.00	0.00b±0.00	0..00b±0.00	1.12±0.40
Pelegrina exigua	0.00b±0.00	0.00b±0.00	0.40bc±0.21	0.60cd±0.21	0.80bc±0.33	0.20c±0.17	0.80b±0.33	1.60b±0.35	0.00c±0.00	0.60b±0.35	1.00b±0.40	0.80bc±0.33	0.60b±0.35	0.60b±0.35	0.80b±0.33	0.20b±0.17	0.60b±0.35	0.20b±0.17	0.61±0.27
Cheiracanthium inclusum	0.00b±0.00	0.00b±0.00	0.20c±0.17	0.20cd±0.17	0.40c±0.21	0.20c±0.7	0.60b±0.35	0.80b±0.33	1.20bc±0.71	0.80b±0.33	1.20b±0.52	0.60bc±0.35	0.60b±0.35	0.40b±0.21	0.80b±0.33	0.00b±0.00	0.00b±0.00	0.00b±0.00	0.44±0.23
Total	2.00±1.70	2.20±1.25	8.60±2.31	13.20±3.14	11.60±2.99	9.40±2.17	8.80±2.94	9.40±2.71	9.80±3.90	11.00±3.66	10.40±3.33	9.00±3.16	10.80±2.47	11.40±2.61	7.40±2.24	3.40±0.94	3.60±1.52	1.40±0.60	8.63±2.63
LSD (p=0.05)	0.96	0.86	1.57	2.01	1.81	1.73	1.86	1.94	2.22	2.45	2.17	1.51	1.43	1.73	1.48	1.02	1.21	0.66	1.59

*Mean±S.E; Mean of five replications, LSD; Least significant difference, variables ($^{a, b, c..}$) significantly differ from each other at 5% level of significance

The mean population of *C. septumpunctata* was found to be maximum during 2nd fortnight of March. The mean population of *A. imperator* had maximum during 1st fortnight of August. The maximum population of *C. pennsylvanicus* was found in 1st fortnight of April. *Z. bicolorata* was found to be maximum during 2nd fortnight of March. Rest of the other natural enemies *P. exigua* had maximum mean population during 2nd fortnight while *C. inclusum* had maximum mean population in 2nd fortnight of June and July.

The current findings on relative abundance of pests and natural enemies were strongly supported by Gacem and Mezerdi (2022) [7], they observed the maximum relative abundance of *M. persicae* with 26.46% followed by *Brachycaudus helichrysi* with 4.85%. They also reported that ladybugs dominate in peach orchards compared to hoverflies and green lacewing. The Coccinellidae represent the vast majority of 25.19%, followed by the other species in the peach orchard. The present results on abundance and diversity of various pests and natural enemies in peach revealed that the maximum population of pests was observed in April to July and was peaked in month of June and July which was strongly supported by Kumar *et al.* (2015) [15] he reported that the incidence of *T. urticae* increases from the March and decrease with the change in weather conditions. Akyazi *et al.* (2016) [16] reported that incidence of phytoseiids was maximum during the month of July and it decreases after October. Veerendra *et al.* (2015) [17] and Choudhary (2016) [18] has also reported the presence of mites during the hot and humid months. Brown and Schmitt (2001) [19] indicated the maximum abundance of the insects in peach orchard in the month of May and June and less abundant in July and August. Bouchelta and Allam (2023) [20] observed the population *of T. urticae* on peach initiated in mid-March, gradually increased and peak in the month of May, June and August and then declined later (mid-October). Putman (1967) [21] reported the spider population in peach orchard population was highest in the month of July and declined in the month of August and September. In case of aphids, present finding are in conformity with Sharma and Khokhar (2018) [22] who observed that the mean population of aphid was highest during the month of February and March then declined in the month of April and May. Also similar results were observed by Gacem and Mezerdi (2022) [7] in which they indicated that the natural enemies of aphids appeared in April, the activity of the predators decreased at the end of May and the presence of high ladybird species in the peach. Farooq and Arya (2019) [23] recorded that the different insect pests on peach crop and they revealed that the bugs, aphids and beetles were the most prevalent pests in peach. The maximum diversity of insect pests was observed during the rainy season followed by spring and autumn seasons, and dropped to minimum in the winter season. In case of fruit flies, Sharma *et al.* (2011) [24] also supported the current findings that the population of fruit flies starts building up from April and continues up to October on the peach crop.

3.2 Diversity indices of arthropods

3.2.1 Pollinators

Seven diversity indices were calculated for pollinators in peach orchard (Table 6). The calculated values of Simpson's index (D), Simpson's index of diversity (SID), Simpson's reciprocal index (1/D), Shannon index of diversity (H'), Margalef's index of diversity (D_{mg}), Berger Parker diversity index (d) and Evenness index (E) were ranged from 0.12 to 0.31, 0.69 to 0.88, 3.22 to 8.33, 1.54 to 2.24, 0.72 to 1.10, 0.20 to 0.90 and 0.92 to 1.25 respectively.

The current findings on diversity of pollinators were strongly supported by Dar *et al.* (2018) [25] who observed the pollinators of peach during the blooming period. They revealed the value of Simpson's index (D) of peach pollinators were ranges from 0.1 to 0.3. Bashir *et al.* (2015) [26] who estimated the Simpson index (D) value of pollinator species ranges from 0.06 to 0.11 and Simpson's index of diversity (SID) of pollinator species obtained in present study are same agreement with Bashir *et al.* (2015) [26] who also reported the Simpson index of diversity value ranges 0.70 to 0.87. The value of Shannon index of diversity (H') of peach pollinator species ranged from 1.54 to 2.24, which were strongly supported by Belamkar and Jadesh (2014) [27] who observed that Shannon diversity index (H) ranges from minimum 1.00 to 2.22. Similarly, the Kyerematen *et al.* (2014) [28] studied the species composition and observed the highest Shannon diversity index (H') of 3.9 and insect pollinator species evenness of 0.928 to 0.977. Similarly, Anbalagan *et al.* (2015) [29] observed the evenness species of pollinators from 0.813 to 0.907, they also recorded the value of Berger Parker diversity index from 0.08 to 0.30.

Table 6: Diversity indices of pollinators visiting peach orchard

Time Diversity indices	1st fortnight of February	2nd fortnight of February	1st fortnight of March	2nd fortnight of March	1st fortnight of April	2nd fortnight of April
Simpson's index (D)	0.22	0.13	0.12	0.13	0.31	0.17
Simpson's index of diversity (SID)	0.78	0.87	0.88	0.87	0.69	0.83
Simpson's reciprocal index (1/D)	4.54	7.69	8.33	7.69	3.22	5.88
Shannon index of diversity (H')	1.54	2.24	1.91	1.93	2.10	2.09
Margalef's index of diversity (D_{mg})	0.72	0.81	1.10	1.09	0.98	0.91
Berger Parker diversity (d)	0.30	0.90	0.20	0.21	0.21	0.22
Evenness index(E)	0.96	1.25	0.92	0.93	1.09	1.16

3.2.2 Pests and natural enemies

In case of pests, the calculated values of Simpson's index (D), Simpson's index of diversity (SID), Simpson's reciprocal index (1/D), Shannon index of diversity (H'), Margalef's index of diversity (D_{mg}), Berger Parker diversity index (d) and Evenness index (E) were ranged from 0.00 to 1.00, 0.00 to 0.91, 0.00 to 3.33, 0.00 to 2.27, 0.00 to 0.95, 0.00 to 1.00 and 0.00 to 1.30 respectively (Table 7). In case of natural enemies, the calculated values of Simpson's index (D), Simpson's index of diversity (SID), Simpson's reciprocal index (1/D), Shannon index of diversity (H'), Margalef's index of diversity (D_{mg}), Berger Parker diversity index (d) and Evenness index (E) were ranged from 0.23 to 0.71, 0.12 to 0.77, 1.13 to 4.32, 0.26 to 1.24, 0.02 to 1.26, 0.34 to 0.94 and 0.08 to 1.36 respectively (Table 8).

Table 7: Diversity indices of pests visiting peach orchard

Time / Diversity Indices	1st fortnight of Feb	2nd fortnight of Feb	1st fortnight of March	2nd fortnight of March	1st fortnight of April	2nd fortnight of April	1st fortnight of May	2nd fortnight of May	1st fortnight of June	2nd fortnight of June	1st fortnight of July	2nd fortnight of July	1st fortnight of Aug	2nd fortnight of Aug	1st fortnight of Sept	2nd fortnight of Sept	1st fortnight of Oct	2nd fortnight of Oct
Simpson's index (D)	1.00	1.00	0.90	0.09	0.65	0.46	0.35	0.30	0.30	0.30	0.38	0.35	0.30	0.28	0.38	0.60	0.00	0.00
Simpsons index of diversity (SID)	0.00	0.00	0.10	0.91	0.35	0.54	0.65	0.70	0.70	0.70	0.62	0.65	0.70	0.72	0.62	0.40	0.00	0.00
Simpson's reciprocal index (1/D)	1.00	1.00	1.11	1.09	1.53	2.17	2.85	3.33	3.33	3.33	2.63	2.85	3.33	3.57	2.63	1.66	0.00	0.00
Shannon index of diversity (H')	0.30	0.36	0.65	1.42	2.27	1.99	1.84	1.55	1.45	1.34	1.08	1.12	1.01	0.90	0.44	0.16	0.00	0.00
Margalef's index of diversity (D_{mg})	0.00	0.00	0.20	0.37	0.90	0.90	0.89	0.88	0.91	0.95	0.60	0.65	0.73	0.78	0.70	0.62	0.00	0.00
Berger Parker diversity(d)	1.00	1.00	0.95	0.94	0.79	0.65	0.54	0.45	0.46	0.44	0.54	0.47	0.44	0.40	0.52	0.80	0.00	0.00
Evenness index(E)	0.00	0.00	0.94	1.30	1.26	1.11	1.02	0.86	0.81	0.74	0.78	0.81	0.92	0.82	0.40	0.23	0.00	0.00

Table 8: Diversity indices of natural enemies visiting peach orchard

Time / Diversity Indices	1st fortnight of Feb	2nd fortnight of Feb	1st fortnight of March	2nd fortnight of March	1st fortnight of April	2nd fortnight of April	1st fortnight of May	2nd fortnight of May	1st fortnight of June	2nd fortnight of June	1st fortnight of July	2nd fortnight of July	1st fortnight of Aug	2nd fortnight of Aug	1st fortnight of Sept	2nd fortnight of Sept	1st fortnight of Oct	2nd fortnight of Oct
Simpson's index (D)	0.64	0.38	0.36	0.36	0.29	0.36	0.29	0.25	0.25	0.24	0.23	0.31	0.35	0.48	0.34	0.88	0.41	0.71
Simpsons index of diversity (SID)	0.36	0.62	0.64	0.64	0.71	0.64	0.71	0.75	0.75	0.76	0.77	0.69	0.65	0.52	0.66	0.12	0.59	0.29
Simpson's reciprocal index (1/D)	1.56	2.63	2.77	2.77	3.44	2.77	3.44	4.00	4.00	4.16	4.34	3.22	2.85	2.08	2.94	1.13	2.43	1.40
Shannon index of diversity (H')	0.27	0.26	0.84	1.02	1.05	1.24	0.93	1.01	0.94	1.13	1.12	0.96	1.02	0.91	0.82	0.61	0.46	0.48
Margalef's index of diversity (D_{mg})	0.43	0.83	1.06	0.95	0.98	1.03	1.05	1.03	1.02	1.25	1.26	1.31	1.25	1.23	0.03	0.03	0.06	0.02
Berger Parker diversity(d)	0.80	0.54	0.55	0.54	0.44	0.58	0.47	0.42	0.38	0.34	0.40	0.48	0.57	0.68	0.56	0.94	0.61	0.85
Evenness index(E)	0.39	0.23	0.52	0.63	0.65	0.77	0.58	0.63	0.58	0.63	0.70	0.60	0.63	0.56	1.36	0.08	0.42	0.69

The present results on diversity indices of pests and natural enemies were supported by many researchers Gacem and Mezerdi (2022) [7] observed the highest value of Simpson's Diversity i.e., 0.70 and the maximum value of Shannon's index i.e., 1.29 which were almost similar with the present study. Furthermore, Farooq and Arya (2019) [23] also observed the Shannon diversity index indicated that maximum numbers of species were obtained in month of April (2.47) and decrease in the month of October–February (1.09). The calculated value of evenness was found to be maximum in the month of March (0.99) and lowest in the month of February (0.95). The calculated value of Berger Perker was recorded from 0.10 to 0.20.

4. Conclusion

In peach orchard, total 20 species of arthropods were found including eight species of pollinators, six of species of pests (including 4 insects and 2 mites) and six species of natural enemies (including 4 insects and 2 mites). Apidae was the most abundant family with maximum abundance of *A. mellifera* as compare to other species of pollinators. In case of pests *M. persicae* was the most abundant insect and among natural enemies, *C. septumpunctata* was the most dominant insect. Maximum abundance of all the pests and natural enemies was observed during the months of April to June and that of pollinators was observed during Feb-March. Our research thus providing basic information on the incidence of pests which help in determining the appropriate time of action and suitable methods for pest control.

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6. References

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