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Pollinator's diversity and their abundance on apple bloom from Solan, Himachal Pradesh, India

Preeti Kaundil, Raj Kumar Thakur, Meena Thakur, Harish Kumar Sharma, Shivani Chauhan, Priyanka Rani, Kritika Sood, Sudha Singh, Komal and Rajni Devi

Abstract
The survey was conducted during March-April in Year 2019 and Year 2021 at Solan, Himachal Pradesh, India. Remarks on insect pollinators accrued with the aid of using scan sampling, fluorescent pan traps and sweep net captures during both years demonstrated that 59 insects belonging to 39 genera under 18 families and 5 orders have been recorded on apple bloom. Hymenopterans have been recorded as most dominant visitors followed by Dipterans, Lepidopterans, Coleopterans and Thysanopterans. Data on number of trapped insect in fluorescent pan traps revealed that 'other insect visitors' (0.89/trap) (*Ceratina binghami*, *Amegilla* sp., *Megachile* sp., *Andrena* sp., *Astata* sp., *Halictus lucidipennis*, *Lasioglossum* sp., *Vespa* sp., *Episyrphus balteatus.*, *Eristalis tenax*, *Musca* sp.) were mostly trapped insects and the minimum trapped insect visitors were Lepidopterans (0.22/trap. By scan sampling method, *A. mellifera* (5.46/500 flowers/2m^2 in 10 minutes) was statistically most abundant insect visitor and the minimum abundance of insect visitors were recorded from Lepidopterans (0.27/500 flowers/2m^2 in 10 minutes). *A. mellifera* (1.04/5 sweeps) gets captured in huge quantity through sweep net captures.

Keywords: Insect visitors, apple, traps, sampling

Introduction
A crucial ecological service, pollination promotes the survival of plant species, particularly crop plants, and helps to maintain biodiversity. One can give thanks to a bee, butterfly, bat, bird, or other pollinator for one out of every three bites consumed. The public is concerned about any loss of biodiversity, but the loss of pollinating insects may be especially problematic due to the possible impacts on plant reproduction and, consequently, the security of the food supply. Many agricultural plants and wild plant populations rely on pollination, frequently from uncontrolled, wild pollinator communities. (Free, 1993; Kluser and Peduzzi, 2007) [4, 9].
According to estimates by Ollerton *et al*. (2011) [25], 85 percent of flowering plant species depend on animals, primarily insects, for pollination, and crop pollination has an estimated yearly economic value of $153 billion worldwide (Gallai *et al*., 2009) [5]. Insects that visit flowers perform an essential ecosystem function for the production of the world's crops, according to Mattu (2013) [22]. Urbanization and other land-use practises are impacting the available natural habitats quickly, which is putting strain on the ecological services provided by wild pollinators. Without the employment of managed and unmanaged pollinators, other agronomic procedures like manuring, insecticides, fertilisers, etc., which are extremely cost-effective, may not produce the intended results for increasing the productivity levels of various crops by pollination.
The Himalayan belt's main income crop among the temperate fruit crops has recently been the apple. It alone accounts for 78 per cent of overall fruit production and 48% of the area under all fruits. From 35,076 ha in 1975-1976 to 99,564 ha in 2009-2010, an annual growth of 3.14 percent was registered in the area used for apple production (Singh *et al*., 2012). Despite an increase in the area planted with apples in recent years, the production of apples per hectare has decreased. In order to increase apple production in the state, it is necessary to modify techniques and explore for other potential inputs, such as making full use of underutilised and environmentally friendly resources like bee pollination. (Verma and Jindal, 1997; Mattu *et al*., 2012b; Mattu and Mattu, 2013 [22]; Mattu, 2014) [32, 22, 21]. Honeybees eat pollen and nectar, which are the basic ingredients in the beekeeping industry. Foraging behaviour refers to the collecting of pollen and nectar by bees from flowering plants.

The bulk of pollinating insects in the Himalayan region, including honey bees, are used to pollinate apple orchards. (Free, 1993) [4].

However, very little is known about how diverse insect visitors, such as honeybees, contribute to the pollination of different horticulture crops in India, particularly in Himachal Pradesh (Mishra *et al*., 1976; Mattu and Verma, 1985; Verma, 1990; Kumar, 1997; Mattu and Bhagat, 2015) [23, 18, 33, 11, 12]. In order to understand the variety, distribution, and relative abundance of various insect species visiting apple crops in Solan, Himachal Pradesh, India, the current investigation was carried out.

Materials and Methods

Survey and collection: The samples of insects visiting apple orchard flowers were collected from Nauni, Solan (about 1260 m amsl, 30°N latitude and 77 °N) (Figure. 1)

Fig 1: Site of collection of pollinators from Nauni (Solan)

Climatic characteristics: Average maximum temperature during 25 March-15 April, in Year 2019 and Year 2021 was 25.82 ℃ and 28.07 ℃. Average minimum temperature during March-April, in Year 2019 and Year 2021 was 11.02 ℃ and 10.41 ℃. Slight fluctuations in maximum and minimum temperature was observed during both years. Average relative humidity during March-April in Year 2019 was 47.8 per cent which was comparatively lesser than the average relative humidity of 43.66 per cent during March-April in Year 2021 (Table 1).

Table 1: Temperature and relative humidity during Year 2019 and Year 2021 at Nauni (Solan), Himachal Pradesh

Days	Year-2019			Year-2021		
	Maximum Temperature	Minimum Temperature	Relative Humidity (%)	Maximum Temperature	Minimum Temperature	Relative Humidity (%)
1	16	11	65	26	7.8	33
2	24	7.5	42	29	6.8	37
3	23.5	9	49	30	8.6	79
4	27	9.7	50	31	10.4	47
5	26.5	11	43	31.2	13.6	45
6	26.5	10	41	28	6.8	33
7	27	11	43	27.2	6.5	27
8	27.2	11.4	47	30.6	7	50
9	27.5	12.8	46	29.6	12	49
10	27	13.4	57	29	12.4	45
11	26.5	10	41	32	11.6	33
12	27	11	43	31.5	12.6	78
13	27.2	11.4	47	31.4	12.7	25
14	27.5	12.8	46	33	13.5	38
15	27	13.4	57	32.8	13.8	36

Diversity of insect pollinators: Fluorescent pan traps, sweep net capture, and scan sample techniques were used to record the variety of insect visitation to apples. The Imms' General Textbook of Entomology, published by Richards and Davis, contains taxonomic keys that were used to identify the many insect visitors (1977) [27].

Scan sampling: Observation on diversity was recorded on 500 flowers/2m^2 in 10 minutes on 5 sunny days. The sampling was done by walking slowly along a set path in between rows. The insect visitors were counted by looking at each flower one by one in sequence.

Fluorescent pan traps: Insect diversity was investigated using Campbell and Hanula's technique (2007) [1]. Plastic bowls were manually painted with neon yellow and blue aerosol paint to create fluorescent coloured pan traps. Fluorescent yellow, blue, and white pan traps were employed. Three-fourths of these traps were filled with water, and a few drops of detergent were added to reduce surface tension,

allowing the caught bug to sink into the water. The observations were conducted using 24 bowls. The colours of these bowls were alternated throughout the transect, which was laid out in three lines. Two metres apart, the bowls were positioned so that no one bowl was hidden by vegetation and that insects could easily see it. Traps were placed prior to 0900 h in the morning and removed after 1500 h. Observations were recorded during onset of bloom, full bloom and end of bloom for 5 sunny days. (Figure 2)

In order to remove pollen, dirt, and nectar that had been regurgitated, the insects from the traps were properly sieved and cleaned with water. Then, the insects were placed in tiny vials of 70 per cent alcohol to preserve them. By dividing the total number of insects caught by all of the traps, the number of insects caught per bowl was calculated.

Fig 2: Traps placed in apple filed to attract the pollinators

Sweep net captures: The sweep net captures were taken as per method given by Westphal *et al*. (2008) [34]. Five such transect were used for recording observations. Insect collection net sweeps were taken at all the random five spots equally distributed in the crop orchard. Observations were recorded during different day hours (1000, 1300 and 1500 h) at onset of bloom, full bloom and end of bloom.

Statistical analysis: The data on various aspect was statistically analysed using online software OPSTAT developed by Professor O.P. Sheoran.

Results

The observations on insects collected by different sampling methods at Nauni (Solan) during March-April of 2019 and 2021 year documented 59 insects belonging to 39 genera under 18 families and 5 orders (Table 2). During 2019, 44 insects belonging to 35 genera under 18 families and 5 orders (Table 2) were recorded. Hymenopteran belonged to 12 families namely Apidae (8), Megachilidae (1), Andrenidae (1), Crabonidae (1), Halictidae (4), Vespidae (4), Chrysididae (1), Pompilidae (1), Formicidae (1), Ichneumonidae (1), Scoliidae (2), Sphecidae (2). *A. cerana, A. mellifera, A. florea, C. binghami, X. amethystine, X. violacea, B. haemorrhoidalis, Amegilla* sp. represented the family Apidae. Megachilidae (*Megachile* sp.), Andrenidae (*Andrena* sp.), Crabonidae (*Cerceris* sp.), Halictidae (*H. lucidipennis, Halictus* sp.2, *Halictus* sp.3 and *Lasioglossum* sp.1. Vespidae (*Vespa* sp.1, *Vespa* sp.2, *Vespa* sp.3 and *Polistes* sp.), Chrysididae (*Chrysis* sp.1), Pompilidae (*Anoplius* sp.), Formicidae (*Formica* sp.), Ichneumonidae (*Megarhyssa* sp.), Scoliidae (*Campsomeris* sp. and *Scolia* sp.), Sphecidae (*Sceliphron* sp. and *Chalybion bengalense*). Dipterans with 7 specimens belonging to 2 families. 8 species were from family Syrphidae (*E. balteatus, Sphaerophoria indiana, E. tenax, Eristalis* sp.1, *Ischiodon scutellaris, M. confrater, Melanostoma* sp. and *E. frequens*) and Muscidae (*Musca* sp.). Lepidoptera had 4 specimens belonging to 2 families. 1 species were from family Pieridae (*P. brassicae*) and 3 from family Nymphalidae (*Aglais cashmiriensis, Junonia* sp. and *Vanessa cashmiriensis*). Coccinelidae (*C. septempunctata, Coccinella* sp. and *Hippodamia variegate*) and Thripidae (*Thrips* sp.).

During 2021, 47 insects belonging to 31 genera under 16 families and 5 orders (Table 2) were recorded. Hymenopteran visitors belonged to 10 families namely Apidae (8), Andrenidae (1), Crabonidae (2), Halictidae (8), Vespidae (4), Chrysididae (1), Pompilidae (1), Formicidae (1), Scoliidae (1), Sphecidae (1). *A. cerana, A. mellifera, A. florea, C. binghami, X. amethystine, X. fenestrate, Vespa* sp., *B. haemorrhoidalis, Amegilla* sp. represented the family Apidae. Andrenidae (*Andrena* sp.1), Crabonidae (*Cerceris* sp. and *Astata* sp.), Halictidae (*H. lucidipennis, H. propinquus, Halictus* sp.1, *Halictus* sp., *Halictus* sp.3, *Halictus* sp. 4, *Sphecodes albifrons* and *Sphecodes* sp.1), Vespidae (*Vespa* sp.2, *Vespa* sp.3, *Vespa* sp.4 and *Polistes* sp.), Chrysididae (*Chrysia* sp.2), Pompilidae (*Anoplius* sp.), Formicidae (*Formica* sp.), Scoliidae (*Scolia* sp.), Sphecidae (*Ammophila* sp.). Diptera with 11 specimens belonging to 2 families. 10 species were from family Syrphidae (*E. balteatus, S. indiana, E. tenax, Eristalis* sp.1, *Eristalis* sp.2, *I. scutellaris, M. confrater, Betasyrphus* sp., *E. corollae, E. frequens*) and Muscidae (*Musca* sp.). Lepidoptera had 4 specimens belonging to 2 families. 1 species were from family Pieridae (*P. brassicae*) and 3 from family Nymphalidae (*A. cashmiriensis, Junonia* sp. and *V. cashmiriensis*). Coccinelidae (*C. septempunctata, Coccinella* sp. and *H. variegate*) and Thripidae (*Thrips* sp.).

Table 2: List of insects collected by different sampling methods from Nauni, Solan in 2019 and 2021

Order	Family	Scientific Name	2019	2021
Hymenoptera	Apidae	*Apis cerana* Fabricus	✓	✓
		Apis mellifera Linnaeus	✓	✓
		Apis florea Fabricius	✓	✓
		Ceratina binghami Cockerell	✓	✓
		Ceratina sp.1	-	✓
		Xylocopa amethystine (Fabricus)	✓	✓
		Xylocopa fenestrate Fabricius	-	✓
		Xylocopa violacea Linnaeus	✓	-
		Bombus haemorrhoidalis Smith	✓	✓
		Amegilla sp.	✓	✓
	Megachilidae	*Megachile* sp.	✓	-
	Andrenidae	*Andrena* sp.1	-	✓
		Andrena sp.2	✓	-

	Crabonidae	*Cerceris* sp.	✓	✓
		Astata sp.	-	✓
	Halictidae	*Halictus lucidipennis* Smith	✓	✓
		Halictus propinquus Smith	-	✓
		Halictus sp. 1	-	✓
		Halictus sp. 2	✓	✓
		Halictus sp. 3	✓	✓
		Halictus sp. 4	-	✓
		Lasioglossum sp.1	✓	-
		Sphecodes albifrons Smith	-	✓
		Sphecodes sp. 1	-	✓
	Vespidae	*Vespa* sp. 1	✓	-
		Vespa sp. 2	✓	✓
		Vespa sp. 3	✓	✓
		Vespa sp. 4	-	✓
		Polistes sp.	✓	✓
	Chrysididae	*Chrysis* sp. 1	✓	-
		Chrysis sp. 2	-	✓
	Pompilidae	*Anoplius* sp.	✓	✓
	Formicidae	*Formica* sp.	✓	✓
	Ichneumonidae	*Megarhyssa* sp.	✓	-
	Scoliidae	*Campsomeris* sp.	✓	-
		Scolia sp.	✓	✓
	Sphecidae	*Ammophila* sp.1	-	✓
		Sceliphron sp.	✓	-
		Chalybion bengalense Dahlbom	✓	-
Diptera	Syrphidae	*Episyrphus balteatus* (De geer)	✓	✓
		Sphaerophoria indiana Bigot	✓	✓
		Eristalis tenax (Linnaeus)	✓	✓
		Eristalis sp.1	✓	✓
		Eristalis sp.2	-	✓
		Ischiodon scutellaris (Fabricius)	✓	✓
		Metasyrphus confrater (Widemann)	✓	✓
		Melanostoma sp.	✓	-
		Betasyrphus sp.	-	✓
		Eupeodes corollae (Fabricius)	-	✓
		Eupeodes frequens (Matsmura)	✓	✓
	Muscidae	*Musca* sp.	✓	✓
Lepidoptera	Pieridae	*Pieris brassicae* (Linnaeus)	✓	✓
	Nymphalidae	*Aglais cashmiriensis* (Kollar)	✓	✓
		Junonia sp.	✓	-
		Vanessa cardui Linnaeus	✓	✓
Coleoptera	Coccinelidae	*Coccinella septempunctata* (Linnaeus)	✓	✓
		Coccinella sp.	✓	✓
		Hippodamia variegate (Goeze)	✓	✓
Thysanoptera	Thripidae	*Thrips* sp.	✓	✓

Apis cerana Fabricus

Apis mellifera Linnaeus

Bombus haemorrhoidalis Smith

Xylocopa amethystine (Fabricus)

Eristalis tenax Linnaeus (female)

Campsomeris sp.

Eristalis tenax Linnaeus (male)

Halictus lucidipennis Smith

Episyrphus balteatus (de Geer)

Eristais tenax Linnaeus

Sphaerophoria indiana Bigot (male)

Fig 3: Important insect visitors on apple bloom

Diversity of insect visitors in apple bloom

Fluorescent pan traps

During 2019: Results clearly revealed that significantly maximum (0.54/ trap) insects were trapped during full bloom followed by onset of bloom (0.47/trap) and end of bloom (0.37/trap. Among all insect visitors, 'Other insect visitors' (0.84/trap) were trapped significantly maximum followed by 'Other dipterans' (0.75/trap), *E. balteatus* (0.71/trap), *A. mellifera* (0.51/trap) and *S. indiana* (0.31/trap). The population of trapped *A. cerana* and *E. tenax* were significantly same (0.44/trap). Minimum number of trapped insects were Lepidopterans (0.08/trap) though at par with wild bees (0.13/trap) (Table 3).

During 2021: 'Other insect visitors' were significantly trapped maximum (0.89/trap) followed by 'Other dipterans' (0.87/trap), *E. balteatus* (0.83/trap), *A. mellifera* (0.65/trap), *E. tenax* (0.60/trap), *A. cerana* (0.55/trap) and *S. indiana* (0.43/trap). Minimum number of Lepidopteran insects (0.12/trap) trapped was significantly at par with wild bees (0.16/trap). Among all trapped insect visitors, 'Other insect visitors' were significantly maximum in number during full bloom (0.92/trap) and same number were trapped during onset of bloom and end of bloom (0.80/trap). During second year, 'Other insect visitors' were also most dominant trapped insects at full bloom (1.00/trap) followed by onset of bloom (0.92/trap) and end of bloom (0.88/trap). In both the years, the minimum trapped insect visitors were of Lepidopterans though significantly at par with wild bees (Table 3).

Pooled (2019 and 2021): Pooled data revealed that among various insect visitors, 'Other insect visitors' were the most dominant trapped insects (0.89/trap) though at par with 'Other dipterans' (0.81/trap) and *E. balteatus* (0.77/trap) followed by *A. mellifera* (0.58/trap), *E. tenax* (0.52/trap), *A. cerana* (0.49/trap) and *S. indiana* (0.37/trap). The minimum trapped visitors were Lepidopterans (0.10/trap) though significantly at par with wild bees (0.15/trap). Pooled data further indicated that significantly maximum number of insects (0.59/trap) were trapped during full bloom as compared to onset of bloom (0.51/trap) and end of bloom (0.45/trap) (Table 3).

Scan sampling

During 2019: *A. mellifera* (5.00/500 flowers/2m^2 in 10 minutes) was the most abundant insect visitor, differing significantly from all other insect visitors followed by *A. cerana* (4.59/500 flowers/2m^2 in 10 minutes), *E. balteatus* (3.76/500 flowers/2m^2 in 10 minutes), *E. tenax* (3.24/500 flowers/2m^2 in 10 minutes), *S. indiana* (2.94/500 flowers/2m^2 in 10 minutes) and 'Other insect visitors' (2.06/500 flowers/2m^2 in 10 minutes), whereas, significantly minimum abundance was recorded of Lepidopterans (0.20/500 flowers/2m^2 in 10 minutes) followed by bumble bees (0.45/500 flowers/2m^2 in 10 minutes) (Fig. 2)

During 2021: The activity of insect visitors on the flower of apple during the year 2 is presented in the Figure 2. Data revealed that among *A. mellifera* (5.93/500 flowers/2m^2 in 10 minutes) was significantly most abundant insect visitor followed by *A. cerana* (5.31/500 flowers/2m^2 in 10 minutes) and *E. balteatus* (4.19/500 flowers/2m^2 in 10 minutes). The population of *E. tenax* (3.56/500 flowers/2m^2 in 10 minutes) and *S. indiana* (3.34/500 flowers/2m^2 in 10 minutes) was at par with each other followed by insect visitors (2.57/500 flowers/2m^2 in 10 minutes), whereas, the abundance of Lepidopterans was significantly minimum (0.34/500 flowers/2m^2 in 10 minutes) followed by bumble bees 0.54/500 flowers/2m^2 in 10 minutes).

Pooled (2019 and 2021): The pooled average of relative abundance of different insect visitors foraging apple flowers. The present investigations proved that *A. mellifera* (5.46/500 flowers/2m^{2}in 10 minutes) was significantly most abundant insect visitor and Lepidopterans (0.27/500 flowers/10 min.) were minimum.

Table 3: Number of trapped insects in fluorescent pan traps at different flowering stages at Nauni, Solan in 2019 and 2021

Insect visitors	Number of insects/trap											
	2019				2021				Pooled			
	Onset of bloom	Full bloom	End of bloom	Mean	Onset of bloom	Full bloom	End of bloom	Mean	Onset of bloom	Full bloom	End of bloom	Mean
A. mellifera	0.52 (1.22)	0.56 (1.24)	0.44 (1.19)	0.51 (1.22)	0.68 (1.29)	0.76 (1.33)	0.52 (1.22)	0.65 (1.28)	0.60 (1.26)	0.66 (1.29)	0.48 (1.21)	0.58 (1.25)
A. cerana	0.48 (1.21)	0.52 (1.23)	0.32 (1.14)	0.44 (1.20)	0.52 (1.23)	0.64 (1.28)	0.48 (1.21)	0.55 (1.24)	0.50 (1.22)	0.58 (1.26)	0.40 (1.18)	0.49 (1.22)
E. balteatus	0.72 (1.31)	0.84 (1.35)	0.56 (1.25)	0.71 (1.30)	0.84 (1.35)	0.92 (1.38)	0.72 (1.31)	0.83 (1.35)	0.78 (1.33)	0.88 (1.37)	0.64 (1.28)	0.77 (1.32)
E. tenax	0.48 (1.21)	0.52 (1.23)	0.32 (1.14)	0.44 (1.20)	0.60 (1.26)	0.68 (1.29)	0.52 (1.23)	0.60 (1.26)	0.54 (1.24)	0.60 (1.26)	0.42 (1.19)	0.52 (1.23)
S. indiana	0.32 (1.15)	0.40 (1.18)	0.20 (1.09)	0.31 (1.14)	0.40 (1.18)	0.52 (1.23)	0.36 (1.17)	0.43 (1.19)	0.36 (1.17)	0.46 (1.21)	0.28 (1.13)	0.37 (1.17)
Other dipterans	0.72 (1.31)	0.84 (1.35)	0.68 (1.29)	0.75 (1.31)	0.80 (1.34)	0.92 (1.38)	0.88 (1.37)	0.87 (1.36)	0.76 (1.32)	0.88 (1.37)	0.78 (1.33)	0.81 (1.34)
Lepidopterans	0.08 (1.04)	0.12 (1.06)	0.04 (1.02)	0.08 (1.04)	0.08 (1.04)	0.16 (1.08)	0.12 (1.06)	0.12 (1.06)	0.08 (1.04)	0.14 (1.07)	0.08 (1.04)	0.10 (1.05)
Wild bees	0.12 (1.06)	0.16 (1.07)	0.12 (1.06)	0.13 (1.06)	0.16 (1.08)	0.20 (1.09)	0.12 (1.06)	0.16 (1.07)	0.14 (1.07)	0.18 (1.08)	0.12 (1.06)	0.15 (1.07)
Other insect visitors	0.80 (1.34)	0.92 (1.38)	0.80 (1.34)	0.84 (1.35)	0.92 (1.38)	1.00 (1.41)	0.88 (1.37)	0.93 (1.39)	0.86 (1.36)	0.96 (1.40)	0.84 (1.35)	0.89 (1.37)
Mean	0.47 (1.20)	0.54 (1.23)	0.39 (1.17)	0.46 (1.20)	0.56 (1.24)	0.64 (1.27)	0.51 (1.22)	0.57 (1.24)	0.51 (1.22)	0.59 (1.25)	0.45 (1.20)	0.51 (1.22)

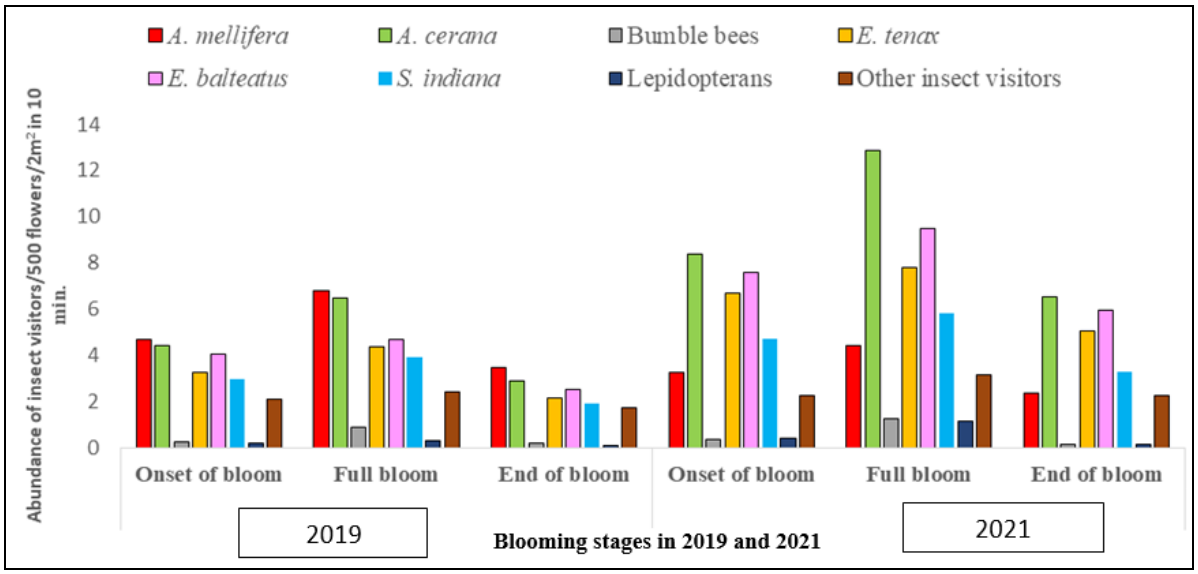

Fig 2: Abundance of insect visitors on apple bloom by scan sampling during March-April in Year 2019 and Year 2021

Sweep net captures

During 2019: Irrespective of blooming period, the insects diversity by sweep net captures was significantly maximum during full bloom (0.56/5 sweeps) followed by onset of bloom (0.42/5 sweeps) and end of bloom (0.36/5 sweeps). Among various insect visitors, *A. mellifera* were found to be the most abundant (0.97/5 sweeps) visitors followed by 'Other dipterans' (0.69/5 sweeps) though at par with 'Other insect visitors' (0.56/5 sweeps). The diversity of *A. cerana* (0.29/5 sweeps) and Lepidopterans (0.29/5 sweeps) was statistically same. The diversity of *S. indiana* (0.24/5 sweeps) and bumble bee (0.03/5 sweeps) was recorded minimum (Fig. 3).

During 2021: Similarly, during second year, significantly maximum insects were also captured in full bloom (0.63/5 sweeps) followed by onset of bloom (0.52/5 sweeps) and end of bloom (0.44/5 sweeps). Among different insect visitors, the diversity of *A. mellifera* (1.11/5 sweeps) was significantly maximum followed by 'Other dipterans' (0.75/5 sweeps), 'Other insect visitors' (0.64/5 sweeps), *E. balteatus* (0.59/5 sweeps), wild bees (0.55/5 sweeps), *E. tenax* (0.49/5 sweeps), *A. cerana* (0.41/5 sweeps), Lepidopterans (0.41/5 sweeps), *S. indiana* (0.15/5 sweeps) and bumble bee (0.01/5 sweeps) which were significantly at par with each other (Fig. 3).

Pooled (March-April Year 1 and March-April Year 2): significantly *A. mellifera* (1.04/5 sweeps) was the most dominant visitors followed by 'Other dipterans' (0.72/5 sweeps) which was at par with 'Other insect visitors' (0.60/5 sweeps). The data also showed that the diversity of *E. balteatus* and wild bees was significantly similar (0.53/5 sweeps) and the diversity of *E. tenax* (0.45/5 sweeps), *A. cerana* (0.35/5 sweeps), Lepidopterans (0.35/5 sweeps) and *S. indiana* (0.29/5 sweeps) was significantly at par with each other. The data further indicated that the diversity of insect visitors was significantly higher at full bloom (0.60/5 sweeps) followed by onset of bloom (0.47/5 sweeps) and end of bloom (0.40/5 sweeps) (Fig. 3).

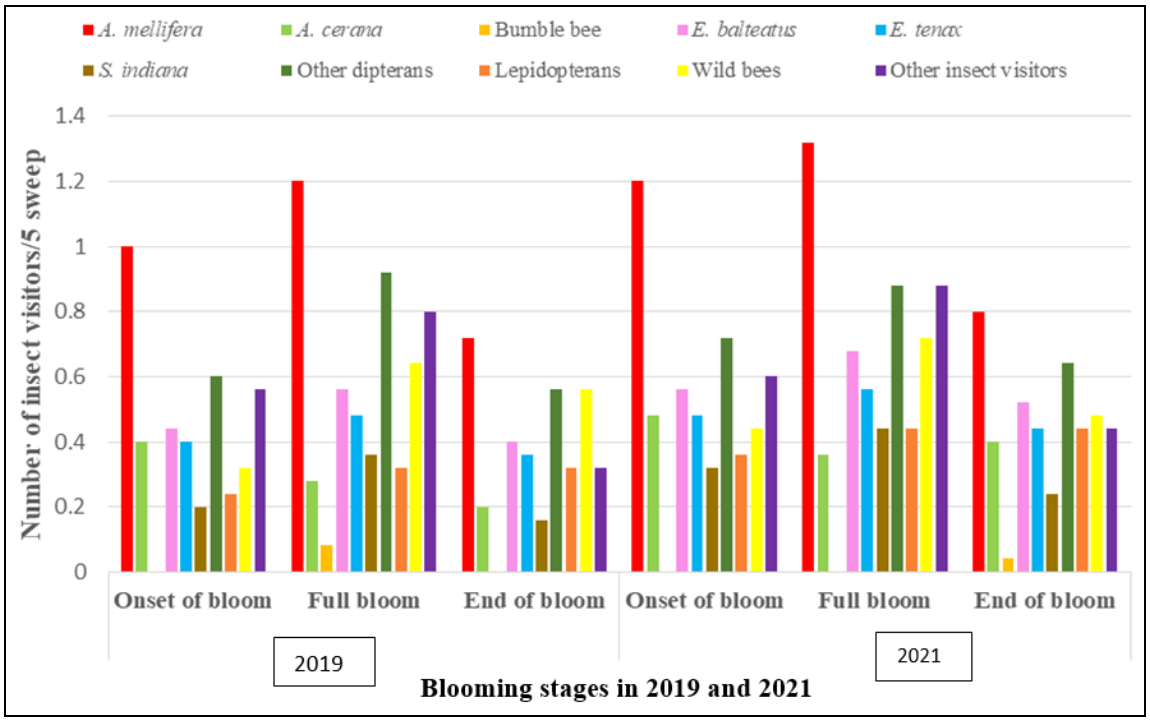

Fig 3: Diversity of insect visitors on apple bloom during by sweep net captures in 2019 and 2021

Discussion

The present findings on collected insect diversity from Shimla, from apple bloom revealed that 69 insects belonging to 42 genera under 18 families and 5 orders. Present studies are in accordance with the work of earlier investigators who have also recorded a variety of pollinators on apple crop in different parts of the continent. For example, Verma and Chauhan (1985) [31] recorded 44 species of insect pollinators on apple bloom of which 16 belonged to Hymenoptera, 11 to Diptera, 9 to Lepidoptera, 7 to Coleoptera and 1 to Hemiptera. Kumar (1988) recorded 16 species of bees visiting apple bloom in Solan area of Himachal Pradesh. A similar survey by Hong *et al*. (1989) [7] revealed a total of 88 species of pollinators on apple, pear and peach flowers in North Korea, whereas, Dashad and Sharma (1993) [2] recorded 19 insect pollinators belonging to 6 families and 11 genera in apple orchards from Solan, Himachal Pradesh. Kumar (1997) [11, 12] observed that apple flowers were visited by 49 insect species in the Himalayan belt. Pollinator diversity studies by Mattu *et al*., (2012a) [20] and Raj *et al*., (2012) [26] also showed that apple flowers were visited by 46 species of insects belonging to 5 orders and 17 families of class Insecta. Ganie *et al*. (2013) showed that apple flowers were visited by 17 species of insect pollinators belonging to 3 orders and 11 families i.e. Hymenoptera, Diptera and Lepidoptera in apple orchards of Kashmir. According to Leksono *et al*. (2013) [13], 935 insect pollinators visited apple blooms, 511 from Poncokusumo (Maliang) and 424 from Bumiaji (Batu). In Poncokusumo, 37.97 per cent of insects belonged to the Syrphidae family, 35.27 per cent to the Vespidae family, 25.16 per cent to the Apidae family, 21.25 per cent to the Sarcophagidae family, and 19.87 per cent to the Tabanidae family, whereas at the other site, Syrphidae (72.15 per cent) was the most dominant family followed by Apidae (41.37 per cent), Pieridae (29.52 per cent) and Nymphalidae (21.75 per cent). Mattu and Bhagat (2015) also recorded 39 species of insects belonging to 6 orders and 19 families from apple flowers at Kullu. Mattu and Nirala (2015) [16] found that apple flowers were visited by 41 species of insects belonging to 5 orders and 16 families of class Insecta in Shimla. Of these, 13 species belonged to Hymenoptera, 17 to Diptera, 8 to Lepidoptera, 2 to Coleoptera and 1 to order Thysanoptera. Mushtaq *et al*., (2018) [24] determined diversity of pollinators visiting apple bloom and revealed that a total of 59 insect visitors belonging to 5 orders and 28 families. Differences in number of species recorded by different workers including the present investigation are attributed to differences in agro climatic conditions of the localities, differential adaptability of a particular native species to its local environmental conditions or due to orientation of other insect visitors to apple during bloom.

Pan traps are a conventional way of assessing insect-flower visitor distributions (Westphal *et al.*, 2008) [34]. The present studies are in line with earlier works on sweet cherry at Kullu conducted by Sharma *et al*., (2009) [29] who observed different types of insect pollinators namely *A. mellifera*, *A. cerana*, syrphids, other Dipterans and Lepidopterans. Sharma *et al*., (2016) [28] also concluded on the basis of a study conducted at Kullu on sweet cherry that other insect visitors (0.83/trap) were the most abundant which included insects from Orthoptera, Coleoptera, Diptera and Lepidoptera. Joshi *et al*. (2015) [8] observed that in apple orchards the honey bee *A. mellifera* were more trapped in fluorescent traps.

Analyses on data on relative abundance of insect visitors on apple bloom it was observed that *A. cerana* was statistically most abundant insect visitor among all other insect visitors. Statistically, maximum activity of insect visitors were observed at full bloom in morning (1000 h) as compared to afternoon and evening hours. It is supported by the findings of previous researchers Mattu and Nirala, 2016 who observed that Indian hive bee, Hymenopterans was the most abundant insect visitor to apple flowers. These results was also in conformity with the earlier observations of Mattu and Mattu (2010) [14] who also reported that honeybees constituted a major proportion of insect pollinators on apple crop. Similarly, Dashad (1989) and Kumar (1997) [11, 12] also recorded Hymenopterans and Dipterans as the most predominant insect species on apple crop and Raj *et al*. (2012) [26] documented *A. cerana* as the most abundant pollinator on apple blossom in Shimla.

Conclusion

The studies clearly revealed that *A. mellifera*, *A. cerana* and other insect visitors are the main visitors on apple bloom. Their abundance is clearly proved by different sampling methods (scan sampling, fluorescent pan traps and sweep net captures). Lepidopterans, Dipterans, Coleopterans and Thysanopterans are other visitors which contributes in the diversity and abundance of insect pollinators on apple bloom.

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