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Diversity and foraging activity of flower visitors/ pollinators of *Momordica charantia* L., in Tamil Nadu, India

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ABSTRACT: Periodical field surveys were conducted in bitter gourd fields at weekly intervals in two locations at N. Poolampatti village, Vaiyampatti block, Tiruchirapalli district to study the diversity of insects visiting bitter gourd flowers. During the study 51 species of flower visitors/ pollinators were recorded which include 19 species of Hymenoptera, 15 species of Lepidoptera, seven species of Diptera and six species of Coleoptera. *Tetragonula iridipennis* was the most abundant pollinator followed by *Apis florea, Halictus* sp. and *Apis cerana indica;* while *Syrphus ribesii* was the dominating Dipteran pollinator. Among the Lepidopterans, *Pachliopta hector* was the major pollinator followed by *Danaus chrysippus*, *Tirumala limniace* and *Delias eucharis.* Species richness (S) was at its maximum (26 species) at 0800 – 1000 hours and minimum (07 species) at 1600-1800 hours. Shannon's and Simpson's diversity indices were maximum at 1000-1200 hours with 2.52 and 9.13 respectively. Shannon's evenness ranged from 0.44 – 0.86 and Simpson's evenness was 0.28 – 0.54 with maximum at 1000-1200 hours.

KEY WORDS: Abundance**,** indices, species diversity, species richness

INTRODUCTION

Bitter gourd, *Momordica charantia* L. is an internationally known plant consumed for its beneficiary health effects. It is also known as bitter gourd, bitter melon, bitter cucumber, balsam pear and African cucumber. Bitter gourd can be consumed in vegetable form, juice, or can be made in smoothie. It has many culinary uses and in folk medicine (Heiser, 1979). India, China, Latin America and Africa have been using bitter gourd in their ancient traditional medicines. The extract of bitter gourd possess antioxidant, antimicrobial, antiviral, anticarcinogenic and antihepatotoxic properties and also lowers blood sugar (Welihinda *et al.,* 1986; Raman and Lau, 1996). Ethano-medical reports indicate use of bitter gourd in folkloric medicine treatment of various ulcers, diabetes and several other infections (Gürbüz *et al.,* 2000; Scartezzini and Speroni, 2000; Beloin *et al.,* 2005). Among the 20 cucurbits cultivated in India, bitter gourd is one of the most important vegetable crops belonging to the family Ccurbitaceae. It is widely distributed in China, Malaysia and tropical Africa (Bailey, 1949). It is cultivated throughout India and is also found growing as a crop in many parts of the country.

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The fruits are relatively inexpensive source of proteins, (1.6 g/100 g of fruit), minerals (0.08 g), rich in Vitamin C and yields 25 k Cal/100 g of fruit. It is supposed to be laxative, wormicide, blood purifier and said to be curative for rheumatism, diabetes and asthma.

Flowering phenology of cucurbits ensures cross-pollination for better fruit set and yield. The flowers of cucurbits are usually monoceious *i.e.* they produce male and female flowers separately on the same plant but at different internodes. The flowering ratio of male to female is 15:1. The pistillate and the staminate flowers open on the same day. But the male flowers are borne first, a fortnight earlier than the female flower. Flowers arise singly from different internodes. Insects are required for pollen transfer because of the large sized pollen grains, their stickiness, and the way they are released from the anthers (Lauria and Fred, 1995). The female flower borne on ovary i.e., inferior ovary and the stigma is receptive throughout the day. In male flowers, anthers dehisce when the corolla expands but the pollens remains on the anther as a sticky mass. The maximum pollination occurs in the forenoon. In the afternoon, the female flower closes but never reopens whether or not pollination has taken place. Highest per cent of fruit set resulted from deposition of pollen on the stigma between 0900 to 1200 hours of the day (Bailey, 1949). Cucurbits flowers are visited by a wide range of insect pollinators. Species of bees, wasps, ants, butterflies, flies, and beetles have been reported to provide pollination services to cucurbit flowers (Delaplane *et al.,* 2000, Free, 1993; McGregor, 1976). Pollinators are simultaneously vital to supporting both natural ecosystems and human food security, which is a unique position for such a diverse group of organisms. The past two decades have seen unprecedented interest in pollinators and pollination ecology, stimulated in part by concerns about the decline of pollinator abundance and diversity in some parts of the world (Ollerton, 2017). Bees are the most studied and utilized pollinators for cucurbit crops throughout the world and provide the greatest contribution to the pollination of cucurbits (Delaplane *et al.,* 2000; Garibaldi *et al.,* 2013). Hence the present study was undertaken to record the diversity of insects (floral visitors/ pollinators) visiting bitter gourd flowers.

MATERIALS AND METHODS

Periodical field surveys were conducted in bitter gourd fields at weekly intervals in two locations at N. Poolampatti (10.6344^{o} N and 78.3110^{o} E) village, Vaiyampatti block, Tiruchirapalli district during *Kharif*, 2018 with two replications to study the diversity of insects visiting bitter gourd flowers. The experimental plot was kept free from chemical sprays during the flowering period. The diversity of floral visitors/ pollinators of bitter gourd were recorded in five randomly selected one square meter area during flowering period at 0600 - 0800, 0800 - 1000, 1000 - 1200, 1200 - 1400, 1400 - 1600 and 1600 - 1800 hours for five minutes in each randomly selected one square meter area using an insect net in 5 spots. These observations were started at 10 per cent bloom and continued at weekly intervals for twenty two weeks. The data were later averaged time-wise and group-wise to infer the pollinator fauna as well as the dominance of particular group. Insects foraging on pollen and nectar from the flower have also been recorded by observing the foraging activity of the insect visually to know the role of the flower visitors in pollination service. Honeybees with their activity of extending their proboscis into the flowers are considered as nectar collectors and bees carrying pollen on their hind legs were determined as pollen collectors (Balachandra *et al*., 2014).

Relative abundance, species richness and Shannon's and Simpson's diversity indices were also calculated as a mathematical measure of species diversity and evenness of species as mentioned below. Insect specimens were collected from the field with aerial nets and preserved in 70 per cent ethanol and photographed in stereo-zoom microscope (AXIOCAM) at the Centre of Innovation, Agricultural College and Research Institute, Madurai.

Species Richness (S): Number of different species present in a community; number of pollinators visiting the flowers in a time period.

Diversity indices were calculated to understand the rarity and commonness of species in a community which is an important tool for understanding community structure.

(a) Shannon's diversity index (H): The proportion of species *i* relative to the total number of species (p*i*) was calculated and was summed across species and multiplied by -1 (Davila *et al.,* 2012).

$$H = - \sum^{s}_{i=0} pi \ln pi$$

The total number of species in the community known as species richness (S) was found out. Shannon's equality (EH) was calculated by dividing H by Hmax (here Hmax = lnS). Equality assumes a value between 0 and 1 being complete evenness.

$$EH = H/H\max = H / \ln (S)$$

(b) Simpson's diversity index (D): The proportion of species I relative to the number of species (*pi*) was calculated and squared. The squared proportions for all the species were summed and the reciprocal was taken.

$$D = 1/\sum^{s}_{i=1} pi^2$$

Equitability (ED) was calculated by taking Simpson's index (D) and it as a proportion of maximum value D could assume if individuals in the community were completely evenly distributed (Dmax) which equals S.

$$ED = D/D \max$$

(c) Species composition: Number of species belonging to each category was calculated as species composition (abundance). Species composition percentage was calculated by dividing number of species in each group by total number of species and multiplied with 100.

(d) Relative Abundance (RA): Relative abundance of a species or a group of species in the community (floral visitors/ pollinators) was calculated by dividing total number of species present by total number of individuals in a group/ community. RA(%) calculated to find how a particular group of species is common or rare among the total pollinators available/ recorded. Thus, can find the efficiency of a particular pollinator among all the other pollinators.

$$\text{Relative abundance (\%)} = \frac{\text{No. of species present}}{\text{Total no. of species}} \times 100$$

Statistical analysis: The mean values were square root transformed and compared by Least Significant Difference (LSD) at 5 per cent probability with AGRES software to assess the effective pollinator and peak hours of pollination services provided by the pollinators.

RESULTS AND DISCUSSION

Floral visitors/ pollinators collected were from five different orders *viz.,* Hymenoptera (37.26%), Diptera (13.72%), Lepidoptera (29.41%), Coleoptera (11.76%) and Hemiptera (3.93%). Order Araneae contributed two species *Oxyopes javanus* and *Neoscona* sp. (3.93%). In general the activity of the pollinating insects like honey bees, other solitary bees and butterflies were higher in the morning hours from 0600 hours to1200 hours. Diversity of floral visitors *i.e.* number of species was higher during the mid-hours (1200 to 1400 hours). In the order Hymenoptera, family Apidae dominated in pollinating bitter gourd flowers with six species, where three species *viz., Apis cerana indica, Apis dorsata* and *Apis florea* contributed maximum. Other pollinators under the family were *Tetragonula iridipennis*, *Amegilla zonata* and an unidentified species. It is followed by Halicitidae family with three species *viz., Halictus* sp*., Lasioglossum* sp. and *Nomia* sp. Xylocopidae, Megachilidae, Chrysididae, Bombicidae, Vespidae and Formicidae were the other families noted as the pollinators/ visitors. Under Lepidoptera, Nymphalidae and Papilionidae dominated with five species each. This was followed by Pieridae with two species. Hesperidae, Noctuidae and Lycaeidae contributed one species each in the pollination services. Among Dipterans, Syrphidae (4 species), Culicidae, Tabanidae and Caliophorodae families (one species each) were recorded. Miridae and Lygaeidae family of the order Hemiptera contributed one species each. Order Coleoptera contributed one species each from Chrysomelidae

Table 1. List of floral visitors/ pollinators in bitter gourd ecosystem

No.	Pollinators	Collecting*	
		Pollen	Nectar
	Order - Hymenoptera		
	Family - Apidae		
1.	*Apis cerana indica* Fab.	yes	yes
2.	*Apis dorsata* Fab.	yes	yes
3.	*Apis florea* Fab.	yes	yes
4.	*Tetragonula iridipennis* Smith	yes	yes
5.	*Amegilla zonata* L.	yes	yes
6.	Unidentified species	yes	yes
	Family - Xylocopidae		
7.	Xylocopa violacea L.	yes	yes
	Family - Halicitidae		
8.	Halictus sp	yes	yes
9.	Lasioglossum sp.	yes	yes
10.	Nomia sp.	yes	yes
	Family - Megachilidae		
11.	Megachile sp.	yes	yes
	Family - Chrysididae		
12.	Chrysis sp.	yes	yes
	Family - Vespidae		
13.	*Polistes gallicus* L.	yes	yes
	Family - Bombicidae		
14.	*Bombus* sp.	yes	yes
	Family - Formicidae		
15.	*Camponotus pensylvanicus*		
	De Geer	No	yes
16.	*Monomorium minimum* Buckley	No	yes
17.	*Dorymyrmex* sp.	No	yes
18.	*Technomyrmex albipes* Smith	No	yes
	Family Trichogrammatidae	No	yes
19.	*Trichogramma pretiosum* Riley	No	yes
	Order - Diptera		
	Family - Syrphidae		
20.	*Syrphus ribesii*	No	yes
21.	*Episyrphus* sp.	No	yes
22.	*Eristalis* sp.	No	yes
23.	*Ischiodon scutellaris* F.	No	yes
	Family Calliophoridae		
24.	*Licilia* sp.	No	yes
	Family Tabanidae		
25.	*Tabanus* sp.	No	yes
	Family Culicidae		
26.	*Culex quinquefasciatus* Say	No	yes

No.	Pollinators	Collecting*	
		Pollen	Nectar
	Order Lepidoptera		
	Family - Nymphalidae		
27.	*Danaius chrysippus* L.	No	yes
28.	*Danaus genutia* Cramer	No	yes
29.	*Eurema hecabe* L.	No	yes
30.	*Eurema blanda* Boisduval	No	yes
31.	*Tirumala limniace* Cramer	No	yes
	Family - Papilionidae		
32.	*Delias euchrasis* Drury	No	yes
33.	*Papilio demoleus* L.	No	yes
34.	*Pachliopta hector* L.	No	yes
35.	*Pachliopta aristolochiae* L.	No	yes
36.	*Pachliopta pandiyana* L.	No	yes
	Family - Pieridae		
37.	*Pieris sp.*	No	yes
	Family - Pieridae		
38.	*Hypolimnas bolina* L	No	yes
	Familiy - Lycaenidae		
39.	*Lampedes boeticus* L.	No	yes
	Family - Hesperiidae		
40.	*Hasora chromus* Cramer	No	yes
	Family - Noctuidae		
41.	*Spodoptera litura* Fab.	yes	yes
	Order - Coleoptera		
	Family - Chrysomelidae		
42.	*Aulacophora fovecolis* Dejean	yes	yes
	Family - Meloidae		
43.	*Hycleus pustulata* Thunberg	No	yes
	Family - Coccinellidae		
44.	*Chilomenes sexmaculata* F.	No	yes
45.	*Illies cincta* F.	yes	yes
46.	*Menochilus sexmaculatus* F.	yes	yes
47.	*Henosepilachna septima* Dieke	No	No
	Order - Hemiptera		
	Family - Miridae		
48.	Unidentified species	No	yes
	Family - Lygaeidae		
49.	*Graptostethus servus* F.	No	yes
	Order - Araneae		
	Family - Oxyopidae		
50.	*Oxyopes javanus*	No	No
51.	*Noescona* sp.	No	No

* Collecting pollen/nectar from the flowers

Table 2. Foraging activity of floral visitors/ pollinators of bitter gourd at different hours of the day

Pollinators	No. of individuals/5min/m²						
	0600 – 0800	0800 – 1000	1000 – 1200	1200 – 1400	1400 – 1600	1600 – 1800	*Mean
***Apis* hymenopterans**							
A. cerana indica	2.53 (1.74)^{b}	2.38 (1.70)^{b}	0.73 (1.11)^{fg}	0.00 (0.71)^{n}	0.00 (0.71)^{i}	0.00 (0.71)^{g}	0.94
A. florea	0.00 (0.71)^{m}	0.28 (0.88)^{hj}	5.02 (2.35)^{a}	2.86 (1.83)^{b}	0.42 (0.95)^{e}	0.00 (0.71)^{g}	1.43
A. dorsata	0.69 (1.09)^{c}	0.82 (1.15)^{dl}	0.11 (0.78)^{lmn}	0.00 (0.71)n	0.00 (0.71)^{i}	0.00 (0.71)^{g}	0.27
Non *Apis* hymenopterans							
T. iridipennis	5.31 (2.41)^{a}	6.22 (2.59)^{a}	3.01 (1.87)^{b}	1.46 (1.4)^{e}	0.24 (0.86)^{g}	0.00 (0.71)^{g}	2.71
A. zonata	0.00 (0.71)^{m}	1.06 (1.25)^{c}	1.2 (1.30)^{de}	0.62 (1.06)^{i}	0.00 (0.71)^{i}	0.00 (0.71)^{g}	0.48
Unidentified apidae	0.00 (0.71)^{m}	0.24 (0.86)^{ijk}	0.29 (0.89)^{jk}	0.02 (0.72)^{mn}	0.00 (0.71)^{i}	0.00 (0.71)^{g}	0.09
Halictus sp.	0.00 (0.71)^{m}	0.65 (1.07)^{e}	2.28 (1.67)^{c}	1.82 (1.52)^{d}	0.28 (0.88)^{f}	0.00 (0.71)^{g}	0.84
X. violacea	0.49 (0.99)^{e}	0.56 (1.03)^{f}	0.02 (0.72)^{mn}	0.00 (0.71)^{n}	0.00 (0.71)^{i}	0.00 (0.71)^{g}	0.18
P. gallicus	0.00 (0.71)^{m}	0.00 (0.71)^{o}	1.02 (1.23)^{e}	0.96 (1.21)^{g}	0.18 (0.82)^{h}	0.00 (0.71)^{g}	0.36
V. orientalis	0.00 (0.71)^{m}	0.22 (0.85)^{ijkl}	0.42 (0.96)^{ij}	0.8 (1.14)^{h}	0.2 (0.84)^{h}	0.00 (0.71)^{g}	0.27
Megachile sp.	0.00 (0.71)^{m}	0.65 (1.07)^{e}	1.24 (1.32)^{dj}	1.08 (1.26)^{f}	0.02 (0.72)^{i}	0.00 (0.71)^{g}	0.50
C. pensylvanicus	0.00 (0.71)^{m}	0.00 (0.71)^{o}	1.28 (1.33)^{d}	0.48 (0.99)^{j}	0.6 (1.05)^{d}	0.2 (0.84)^{d}	0.43
M. mnimum	0.04 (0.73)^{l}	0.42 (0.96)^{g}	2.86 (1.83)^{b}	4.65 (2.26)^{a}	3.04 (1.88)^{a}	1.68 (1.48)^{a}	2.12
Dorymyrmex sp.	0.08 (0.76)^{k}	0.00 (0.71)^{o}	0.00 (0.71)^{n}	0.3 (0.89)^{k}	1.02 (1.23)^{e}	0.16 (0.81)^{e}	0.26
Unidentified	0.04 (0.73)^{l}	0.00 (0.71)^{o}	0.00 (0.71)^{n}	0.02 (0.72)^{m}	0.2 (0.84)^{h}	0.18 (0.82)^{d}	0.07
Dipterans							
C. quinque-fasciatus	0.00 (0.71)^{m}	0.20 (0.84)^{jklm}	0.42 (0.96)^{ij}	0.24 (0.86)^{l}	0.00 (0.71)^{i}	0.02 (0.72)^{f}	0.15
S. ribesii	0.00 (0.71)^{m}	0.28 (0.88)^{hi}	0.48 (0.99)^{hi}	0.01 (0.71)^{mn}	0.24 (0.86)^{g}	0.00 (0.71)^{g}	0.17
I. scutellaris	0.00 (0.71)^{m}	0.00 (0.71)^{o}	0.82 (1.15)^{f}	0.00 (0.71)^{n}	0.00 (0.71)^{i}	0.00 (0.71)^{g}	0.14
Lepidopterans							
D. chrysippus	0.48 (0.99)^{e}	0.20 (0.84)^{jklm}	0.02 (0.72)^{mn}	0.22 (0.85)^{l}	0.28 (0.88)^{f}	0.00 (0.71)^{g}	0.20
D. genutia	0.22 (0.85)^{gh}	0.00 (0.71)^{o}	0.20 (0.84)^{kl}	0.02 (0.72)^{mn}	0.00 (0.71)^{i}	0.00 (0.71)^{g}	0.07

E. hecabe	0.24 (0.86)^{g}	0.20 (0.84)^{jklm}	0.00 (0.71)^{n}	0.00 (0.71)^{n}	0.00 (0.71)^{i}	0.00 (0.71)^{g}	0.07
E. blanda	0.26 (0.87)^{f}	0.16 (0.81)^{m}	0.00 (0.71)^{n}	0.00 (0.71)^{n}	0.00 (0.71)^{i}	0.00 (0.71)^{g}	0.07
T. limniace	0.20 (0.84)^{ij}	0.24 (0.86)^{ij}	0.00 (0.71)^{n}	0.00 (0.71)^{n}	0.42 (0.96)^{e}	0.22 (0.85)^{e}	0.18
D. euchrasis	0.24 (0.86)^{gh}	0.32 (0.91)^{h}	0.00 (0.71)^{n}	0.00 (0.71)^{n}	0.02 (0.72)^{i}	0.00 (0.71)^{g}	0.10
P. demoleus	0.00 (0.71)^{m}	0.18 (0.82)^{klm}	0.03 (0.73)^{mn}	0.00 (0.71)^{n}	0.00 (0.71)^{i}	0.00 (0.71)^{g}	0.04
P. hector	0.67 (1.08)^{d}	0.84 (1.16)^{d}	0.00 (0.71)^{n}	0.00 (0.71)^{n}	0.00 (0.71)^{i}	0.00 (0.71)^{g}	0.25
P. aristolochiae	0.22 (0.85)^{h}	0.20 (0.84)^{jklm}	0.02 (0.72)^{mn}	0.00 (0.71)^{n}	0.00 (0.71)^{i}	0.00 (0.71)^{g}	0.07
P. pandiyana	0.18 (0.82)^{j}	0.16 (0.81)^{lm}	0.00 (0.71)^{n}	0.00 (0.71)^{n}	0.00 (0.71)^{i}	0.00 (0.71)^{g}	0.06
Pieris sp.	0.04 (0.73)^{l}	0.02 (0.72)^{o}	0.00 (0.71)^{n}	0.00 (0.71)^{n}	0.00 (0.71)^{i}	0.00 (0.71)^{g}	0.01
H. chromus	0.21 (0.84)^{i}	0.08 (0.76)^{n}	0.00 (0.71)^{n}	0.00 (0.71)^{n}	0.00 (0.71)^{i}	0.00 (0.71)^{g}	0.06
H. bolina 0.	22 (0.85)^{h}	0.02 (0.72)^{o}	0.12 (0.79)^{lm}	0.00 (0.71)^{n}	0.00 (0.71)^{i}	0.00 (0.71)^{g}	0.08
Coleopterans							
Aulacophora sp.	0.00 (0.71)^{g}	0.20 (0.84)^{jklm}	0.42 (0.96)^{ij}	0.22 (0.85)^{l}	0.00 (0.71)^{i}	0.00 (0.71)^{g}	0.14
Coccinellids	0.00 (0.71)^{m}	0.00 (0.71)^{o}	0.62 (1.06)^{gh}	2.02 (1.59)^{c}	1.82 (1.52)^{b}	0.26 (0.87)^{b}	0.79
S.Ed	0.01	0.02	0.04	0.0133	0.01	0.003	
CD	(0.05)	0.02	0.04	0.08	0.0665	0.02	0.007

*Each value is a mean of twenty two observations;
Figures in parenthesis are square root transformed values;
In a column, means followed by same letter(s) are on par by LSD (p= 0.05)

Table 3. Species richness and diversity indices of floral visitors/ pollinators

	Time (hours)					
Parameters	**0600 – 0800**	**0800 – 1000**	**1000 – 1200**	**1200 - 1400**	**1400 – 1600**	**1600 – 1800**
Species richness (S)	19	26	23	18	15	7
Shannon's H index	2.01	2.41	2.52	2.27	2.09	1.30
Shannon's E index	0.68	0.74	0.80	0.79	0.77	0.67
Simpson's D index	4.19	5.77	9.18	7.38	5.49	2.44
Simpson's E index	0.22	0.22	0.40	0.41	0.37	0.35

Table 4. Foraging activity of major bitter gourd pollinators

Pollinator	Foraging hours	Time spent (seconds)*
T. iridipennis	0600 - 1200	48.2(6.94)[a]
A. florea	1000 - 1400	12.18(3.48) [b]
A. cerana indica	0600 - 1000	7.12(2.66)[bc]
A. zonata	1000 - 1400	3.60(1.89)[c]
Halictus sp.	1000 - 1400	8.20(2.86)[b]
Megachile sp.	1000 - 1400	6.32(2.51)[bc]
S.Ed		0.63
CD (0.05)		1.319

and Meloidae and four species from Coccinellidae (Table 1).

The insects visit the flowers for nectar, pollen and extrafloral nectars (*Trichogramma pretiosum*) from flowers (Tian *et al.*, 2016), while some predatory species visits the flowers for their prey. Spiders prey on small pollinating bees that visit the flowers very often for pollen and nectar source *viz., Neoscona* sp. on stingless bees, *T. iridipennis* (Telle *et al.,* 2018). Hemipteran, *Graptostethus servus* F. feed on the moisture present in flowers, shoots, stems and leaves (Chin *et al.*, 2009). Hence all the flower visitors cannot be considered as pollinators.

Foraging activity of flower visitors/ pollinators

Apis florea was the major pollinator followed by *A. cerana indica* and *A. dorsata.* The mean population of *A. florea* was maximum at 1000 - 1200h (5.02/m^2/5 min) followed by 1200 - 1400 hours (2.86/m^2/5 min). At 0600 – 0800, 0800 - 1000h and 1000 - 1200h the total population of *Apis* that visited bitter gourd was 1.07, 1.16 and 1.95/m^2/5min respectively (Table 2). The time spent by *A. florea* and *A. cerana indica* was 12.18 and 7.12 seconds per flower respectively (Table 4).

In non *Apis* hymenopterans, the major pollinator was *T. iridipennis* followed by *Megachile* sp., *Halictus* sp., *A. zonata*, *P. gallicus* and *X. violacea*. The mean population of *T. iridipennis* was found to be maximum (6.22/m^2/5 min) at 0800 to 1000h followed by (5.31/m^2/5 min) at 0600 to 0800h. The total population of non-*Apis* hymenopterans was maximum at 1000-1200h with (1.14/m^2/5 min) and minimum at 1600-1800 hours with (0.19/m^2/5 min). *T. iridipennis* spent on an average 48.20 seconds/ flower while *Halictus* sp. spent 8.20 seconds/ flower. Among Dipterans, *S. ribesii* was the major pollinator followed by

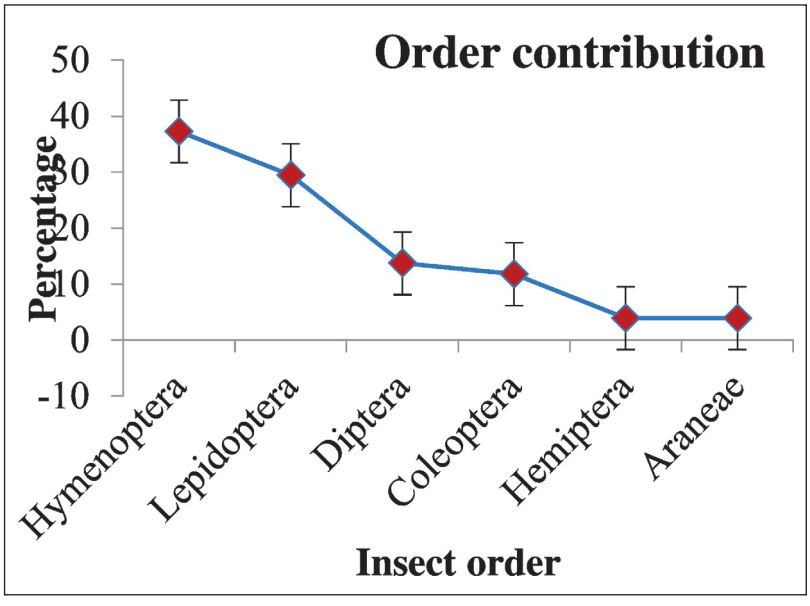

Fig. 1 Flower visitors of bitter gourd ecosystem

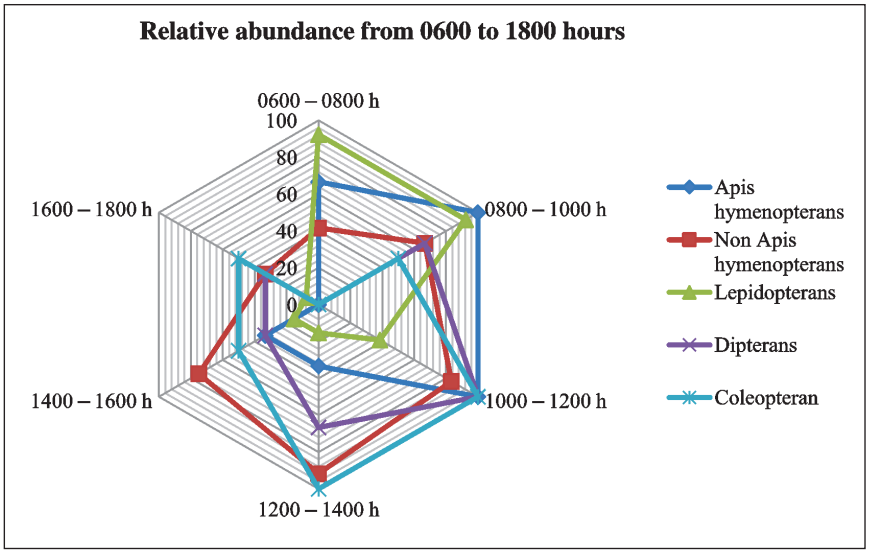

Fig. 2 Relative abundance of floral visitors/ pollinators at different hours in bitter gourd ecosystem

I. scutellaris. The population of Dipterans visiting bitter gourd was maximum at 1000-1200 hours (0.57/m^2/5 min). Amid Lepidopterans, *P. hector* was the major pollinator followed by *D. chrysippus*, *T. limniace, D. euchrasis, H. bolina, D. genutia*, *E. hecabe*, *E. blanda, P. aristolochiae, P. pandiyana, Pieris* sp.,and *P. demoleus.* Lepidopterans were at their maximum at 0600 -0800 and 0800-1000 hours with 0.24 and 0.20/m^2/ 5min and minimum during 1200 – 1400 and 1600 – 1800 hours with 0.02/m^2/ 5 min. Lepidopterans were found during all hours of the day (Table 2).

During 0600-1000 hours, *T. iridipennis, A. cerana indica, A. dorsata, X. violacea* and *P. hector* were the major pollinators along with *Halictus* sp. from 0800 – 1000 hours. While *A. florea, T. iridipennis, Halictus* sp. and *A. zonata* were dominating pollinators during 1000 – 1200 hours. Major bee pollinators and their peak foraging hours in bitter gourd indicate *T. iridipennis, A. florea, Halictus* sp. and *A. cerana indica* are effective pollinators. In general, Apis hymenopterans activity was high during the forenoon while non-Apis hymenopterans and Dipterans were slightly higher during the afternoon. Lepidopterans were found at all times of the day with maximum activity in the morning hours (Table 2, 4).

Species richness and Diversity indices

Species richness and relative abundance were calculated to insist on the commonness of a species and its importance and effectiveness as a pollinator. Shannon's and Simpson's diversity indices were calculated as a mathematical measure of diversity and abundance. Shannon's diversity (H) and Shannon's evenness (E) indices deals with diversity i.e. Shannon's H and E increases as diversity of species increases while, Simpson's diversity D and Simpson's evenness E increases in relation with the abundance of the species. Shannon's index will be at the maximum when the diversity is higher and Simpson's index will be higher when the abundance of the species is highest. Both Shannon's and Simpson's diversity indices were calculated to compare the diversity and abundance of floral visitors/ pollinator species at different hours of the day and the results obtained were proportional.

Species richness (S) was at its maximum with 26 species at 0800-1000h and minimum at 1600-1800 h (Table 3). Relative abundance of the pollinators was also proportional with Species richness. The results of Shannon's and Simpson's diversity indices depicts that both diversity and abundance of floral

visitors/ pollinator species was maximum at 1000 – 1200h with 2.52 and 9.18 and minimum at 1600 – 1800 hours with 1.30 and 2.44 respectively. Shannon's evenness ranged from 0.67 – 0.80 and Simpson's evenness was from 0.22 – 0.40. The evenness calculated namely Simpson's E and Shannon's E were not much variable during the day with high evenness in periods when the diversity and abundance were high i.e. 1000 – 1200h with 0.40 and 0.80 respectively. It is cognizable that the activity and abundance of pollinators is high from 0600 to 1400 hours of the day (Table 2, 3).

Species composition

Total number of floral visitors/ pollinators recorded in the bitter gourd ecosystem have been divided order-wise to calculate the contribution of each order in the pollination service of bitter gourd. Order Hymenoptera has been divided into two groups namely, *Apis* hymenopterans and Non *Apis* hymenopterans, since the genus *Apis* includes the major pollinators of all crops, the honey bees. Order hymenoptera holds the maximum share of pollinators of 45.46 per cent (*Apis* hymenopterans 9.09% and Non *Apis* hymenopterans (36.36%)) followed by Lepidopterans (39.40%), Dipterans (9.09%) and Coleopterans (6.07%) (Fig. 1).

Relative abundance

Relative abundance (RA%) of *Apis* hymenopterans were in the peak from 0600h to 1000 hours which decreased thereafter. While the RA of non *Apis* hymenopterans were maximum during 0800 – 1000 hours chased by 1200 – 1400, 1400 – 1600 and 0800 – 1000 hours respectively, whereas 0600 – 0800 and 1600 – 1800 hours had shown the least activity. Abundance of Lepidopterans was ultimate during 0800 – 1000 hours, whilst the Dipterans showed interest from 1000 – 1400h (Fig. 2).

The present results are in accordance with reports of Subhakar *et al.* (2013), who reported that *T. iridipennnis*, *H. guttuorosus* and *A. florae* were the major pollinators in bitter gourd among the 14 species of pollinators recorded. Further, the findings are also in line with the findings of Bodlah and Waqar (2013) who recorded eight species of pollinators visiting ridge gourd, bitter gourd and brinjal where hymenopterans dominated with six species. Balina *et al.* (2012) studied the diversity, abundance and pollination efficiency of native bee pollinators of bitter gourd in India and recorded nine bee species from three families (Apidae, Halictidae and Megachilidae). Abundance of *Halictus* sp. was maximum followed by *Megachile* sp. and *A. dorsata,* which coincides with the present findings. *T. iridipennis* and *A. cerana indica* were the most abundant species that visit the bitter gourd flowers. Hence, they can be effectively used for supplementing pollination in bitter gourd to get a higher yield in bitter gourd. Since, the diversity and abundance of floral visitors/ pollinators is high during 1000 – 1200, 0800 – 1000, 1200 – 1400 and 0600 - 0800 hours, spraying insecticides during the morning hours should be avoided to conserve the population and activity of pollinators in bitter gourd.

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