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To study the pollinator fauna of cucumber and their foraging behavior in natural pollination and augmentation of *Apis cerana* & *Apis mellifera* bees to natural pollination

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Abstract

The cucumber flowers were found to be visited by three species of honeybees viz., *A. dorsata*, *A. cerana*, *A. florae* as well as stingless bees, lepidopterans, coleopterans, dipterans and hemipterans. Among different flower visitors, in natural pollination, honey bees were the major visitors of cucumber flower constituted (72.33% of total visitors) which was followed by sting less bees (11.94%), lepidopterans (5.12%), hemipterans (3.92%), dipterans (3.63%) and coleopterans (3.06%) during summer 2018 while during summer 2019, honey bees constituted 74.98 per cent which was followed by stingless bees (8.99%), lepidopterans (4.92%), coleopterans (3.58%), dipterans (4.35%) and hemipterans (3.19%). Among different bee species, *A. dorsata* was the predominant flower visitors constituting 30.46 per cent of total flower visitors during summer 2018 and 31.20 per cent of total flower visitors during summer 2019. The mean activity of total visitors during 2018 was maximum at 11 00 h (12.86 visitors/m²/5 minute). The lowest activity of flower visitors was observed at 13 00 h (1.11 visitors/m²/5 minute). During summer 2019, the mean activity of flower visitors was maximum at 10 00 h (12.96 visitors/m²/5 minute). While the lowest activity of flower visitors was recorded at 14 00 h (0.86 visitors/m²/5 minute). In treatment of augmentation of *A. cerana* bees to natural pollination, during summer 2018, honeybees were the major visitors of bitter gourd flower constituted 70.02 per cent which was followed by stingless bees (9.83%), lepidopterans (6.06%), dipterans (5.10%), coleopterans (4.69%) and hemipterans (4.29%). Similarly, during summer 2019, honeybees constituted 75.64 per cent which was followed by stingless bees (10.18%), lepidopterans (4.69%), dipteran flies (3.62%), coleopterans (2.96%) and hemipterans (2.91%). Among different bee species, *A. cerana* was the predominant flower visitors constituting 36.13 per cent of total flower visitors during summer 2018 and 39.75 per cent during summer 2019. The mean activity of total visitors during 2018 were more at 10 00 h (13.13 visitors/m²/5 minute). The lower activity of flower visitors was observed at 13 00 h (1.14 visitors/m²/5 minute). During summer 2019, the mean activity of flower visitors was more at 11 00 h (18.46 visitors/m²/5 minute). The lower activity of flower visitors was recorded at 14 00 h (1.18 visitors/m²/5 minute).

Keywords: Pollinators, *Apis cerana*, *Apis mellifera*, cucumber, foraging behavior, augmentation

Introduction

Cucumber (*Cucumis sativa* L.) is a widely cultivated summer vegetable crop in the gourd family Cucurbitaceae. It is a monoecious annual climber that has been cultivated for more 3,000 years and is still widely cultivated till today (Adetula and Denton, 2003) ^[1]. Flowering phenology of cucumber ensures better cross pollination, as it produces male and female flowers separately on the same plant at different internodes. The maximum pollination occurs in the forenoon. Female flower closes in the afternoon and never reopens whether or not pollination has taken place; furthermore, the highest per cent of fruit set results from deposition of pollen on the stigma between 09:00 a.m. to 12:00 noon (Bailey, 1949) ^[2]. Among the insect pollinators, honeybees are the most important pollinators. Honeybees pollinate 16 per cent of the total of 0.25 million of flowering plant species in the world and nearly 40,000 species of agricultural plants (Deyto and Cervancia, 2009) ^[4]. Utilization of bees in pollination not only increased the yield of various crops but also improves their quality. It helps for uniform maturity and early harvest of the crop. Looking to the importance of pollination in cucumber, the experiment was planned to investigate the “abundance of different flower visitors and their foraging behavior in cucumber”.

Pollination is achieved by abiotic and biotic means. Abiotic pollination occurs mainly by wind (anemophily) and water (hydrophily). Biotic pollination includes mainly vertebrate pollination (zoophily) and insect pollination (Entomophily).

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Bee, flies, butterflies, moths, wasps, beetles, thrips and some other insects play a major role in pollination process. Among the insects, hymenopterans (largest and diversified assemblages of beneficial insects with nearly 2,50,000 described species) are highly evolved and constitute the most important group of pollinating insects.

Materials and Methods

The experiments were conducted at Farmers field of cucumber in Kukari District Navsari, Gujarat, India during summer 2018 and 2019. The experiment was laid down with three treatments viz., T₁ plot Natural pollination, T₂ augmentation of *A. cerana* bees were made in addition to natural pollination and T₃ augmentation of *A. cerana* bees were made in addition to natural pollination. For the purpose, three different fields with same variety with same sowing dates at a distance of 500 m in the same village were selected. The experimental plots were kept free from any insecticidal sprays during flowering period. Observations on different flower visitors visiting the cucumber in the experimental plots were recorded at weekly interval during flowering period from 06 00 h to 18 00 h for five minutes in each square meter area from five spot during peak flowering period. The data were later averaged time wise and group wise to infer the pollinator fauna as well as the dominance of particular group.

Results and Discussion

Flower Visitors of cucumber plot in T₁ Natural pollination, T₂ augmentation of *A. cerana* bees were made in addition to natural pollination and T₃ augmentation of *A. cerana* bees were made in addition to natural pollination. The cucumber flowers in all the treatments were found to be visited by three species of honeybees viz., *A. dorsata*, *A. cerana*, *A. florea* as well as stingless bees, lepidopterans, coleopterans, dipterans and hemipterans.

In natural pollination, honeybees were the major visitors of cucumber flower constituted during summer 2018 (72.33% of total visitors) which was followed by sting less bees (11.94%), lepidopterans (5.12%), hemipterans (3.92%), dipterans (3.63%) and coleopterans (3.06%). Similarly, during summer 2019, honeybee were the major visitors constituted 74.98 per cent which was followed by stingless bees (8.99%), lepidopterans (4.92%), coleopterans (3.58%), dipterans (4.35%) and hemipterans (3.19%).

In treatment of augmentation of *A. cerana* bees to natural pollination, honey bees were the major visitors of cucumber flower constituted 70.02 per cent which was followed by stingless bees (9.83%), lepidopterans (6.06%), dipterans (5.10%), coleopterans (4.69%) and hemipterans (4.29%) summer 2018, while during summer 2019, honey bees were the major visitors of bitter gourd flower constituted 75.64 per cent which was followed by stingless bees (10.18%), lepidopterans (4.69%), dipteran flies (3.62%), coleopterans (2.96%) and hemipterans (2.91%).

In treatment of augmentation of *A. mellifera* bees to natural pollination, honey bees were the major visitors of cucumber flower constituted 70.02 per cent which was followed by stingless bees (9.83%), lepidopterans (6.06%), dipterans (5.10%), coleopterans (4.69%) and hemipterans (4.29%) summer 2018, while during summer 2019, honey bees were the major visitors of bitter gourd flower constituted 75.64 per cent which was followed by stingless bees (10.18%), lepidopterans (4.69%), dipteran flies (3.62%), coleopterans (2.96%) and hemipterans (2.91%).

The present finding on activities of honeybee's species, *A. florea* was reported predominance with Njoroge *et al.* (2010)^[8] and Ekeke *et al.* (2018)^[5] recorded higher activity of *A. mellifera* Satheesha (2010)^[13] & Revanasidda and Belavadi (2019)^[12] recorded higher activity of *A. cerana*. However, Subhakar *et al.* (2011)^[14] recorded the highest abundance of *T. iridipennis*. Patel (2022 a)^[9] recorded that honeybees were the major visitors of cucumber flower constitution 70.45% of total visitors during the year 2018 of flower visitors on cucumber natural pollination plot. Patel (2022 b)^[10] recorded that honeybees were the major visitors of bitter gourd flower constitution 72.33% and 74.98% of total visitors in natural pollination plot.

Activity of different flower visitors on cucumber flowers in natural pollination

Among different bee species, *A. dorsata* was the predominant flower visitors (1.27bees/m²/5 minute) constituting 30.46 per cent of total flower visitors which was followed by *A. cerana* (1.10 bees/m²/5 minute) and *A. florea* (0.65 bees/m²/5 minute) which constituting 26.30 and 15.57 per cent of total flower visitors, respectively during summer 2018. Similarly, during summer 2019, the maximum bee activity was exhibited by the *A. dorsata* (1.30 bees/m²/5 minute) followed by *A. cerana* (1.17 bees/m²/5 minute) and *A. florea* (0.66 bees/m²/5 minute) which constituted 31.20, 27.96 and 15.82 per cent of total flower visitors, respectively. Apart from honeybees, the activity of stingless bees, lepidopterans, coleopterans, dipterans and hemipterans were reported to be 0.50, 0.21, 0.13, 0.15 and 0.16 visitors/m²/5-minute constituting 11.94, 5.12, 3.06, 3.63 and 3.92 per cent of the total visitors, respectively. The corresponding values for the summer 2019 was 0.38, 0.21, 0.15, 0.18 and 0.13 visitors/m²/5 minute for stingless bees, butterflies, coleopterans, dipterans and hemipterans which constituted 8.99, 4.92, 3.58, 4.35 and 3.19 per cent of the total visitors, respectively. The mean activity of total visitors during 2018 was maximum at 11 00 h (12.86 visitors/m²/5 minute). The lower activity of flower visitors was observed at 13 00 h (1.11 visitors/m²/5 minute). During summer 2019, the mean activity of flower visitors was maximum at 10 00 h (12.96 visitors/m²/5 minute). The lower activity of flower visitors was recorded at 14 00 h (0.86 visitors/m²/5 minute). Maximum activity of *A. dorsata*, *A. cerana* and *A. florea* as well as stingless bee was observed at 11 00 h (4.31 bees/m²/5 minute), 10 00 h (3.69 bees/m²/5 minute), 11 00 h (2.03 bees/m²/5 minute) and 11 00 h (1.40 bees/m²/5 minute), respectively during summer 2018. Whereas minimum activity of visitors was observed at 16 00 h (0.11 bees/m²/5 minute) followed by 15 00 h (0.20 bees/m²/5 minute), 13 00 h (0.11 bees/m²/5 minute) and 14 00 h (0.17 bees/m²/5 minute). During summer 2019, the activity of *A. dorsata*, *A. cerana* and *A. florea* as well as stingless bee was observed maximum at 11 00 h (4.51 bees/m²/5 minute), 10 00 h (4.17 bees/m²/5 minute), 10 00 h (2.51 bees/m²/5 minute) and 11 00 h (1.17 bees/m²/5 minute), respectively while, minimum activity recorded at 13 00 h (0.14 bees/m²/5 minute), 14 00 h (0.09 bees/m²/5 minute), 14 00 h (0.03 bees/m²/5 minute) and 14 00 h (0.06 bees/m²/5 minute), respectively. Apart from bee species, the activities of lepidopterans, coleopterans, dipterans and hemipterans were found maximum at 11 00 h (0.60 visitors/m²/5 minute), 12 00 h (0.29 visitors/m²/5 minute), 11 00 h (0.43 visitors/m²/5 minute) and 11 00 h (0.49 visitors/m²/5 minute), respectively during summer 2018. Minimum activity of visitors was

observed at 13 00 h (0.03 visitors/m²/5 minute) which was followed by 08 00 h (0.09 visitors/m²/5 minute), 13 00 h (0.06 visitors/m²/5 minute) and 15 00 h (0.009 visitors/m²/5 minute). During summer 2019, maximum activity of lepidopterans, coleopterans, dipterans and hemipterans was recorded at 11 00 h (0.54 visitors/m²/5 minute), 11 00 h (0.49 visitors/m²/5 minute), 11 00 h (0.49 visitors/m²/5 minute) and 11 00 h (0.46 visitors/m²/5 minute), respectively while, minimum activity was observed at 13 00 h (0.06 visitors/m²/5 minute), 15 00 h (0.08 visitors/m²/5 minute), 14 00 h (0.11 visitors/m²/5 minute) and 14 00 h (0.03 visitors/m²/5 minute), respectively.

The present finding are more or less in conformity with the earlier workers like Eswarappa (2001) ^[6] reported that the activity of different species of bees in open plots was found to be maximum at 10 00-11 00 h and lowest at 06 00 h. Prakash (2002) ^[11] revealed that the activity of *A. cerana* in open plots was maximum at 10 00 h and lowest at 18 00 h. Patel (2022 a) ^[9], recorded that recorded that forging activity of insect pollinators of cucumber in open pollination among different bee species, the *A. florea* was the predominant flower visitors constitution 39.14 per cent on cucumber natural pollination plot.

Activity of different flower visitors on cucumber flowers in augmentation of *A. cerana* to natural pollination

Among different flower visitors, the honeybees were the major visitors of bitter gourd flower during summer 2018 (70.02%) and summer 2019 (75.64%) of total visitors. Among different bee species, *A. cerana* was the predominant flower visitors (1.50 bees/m²/5 minute) constituting 36.13 per cent of total flower visitors which was followed by *A. dorsata* (0.88 bees/m²/5 minute) and *A. florea* (0.53 bees/m²/5 minute) which constituting 21.26 and 12.63 per cent of total flower visitors, respectively during summer 2018. During summer 2019, the maximum bee activity was exhibited by the *A. cerana* (2.29 bees/m²/5 minute) followed by *A. dorsata* (1.23 bees/m²/5 minute) and *A. florea* (0.84 bees/m²/5 minute) constituted 39.75, 21.29, and 14.60 per cent of total flower visitors, respectively. Apart from honeybees, the activity of stingless bees, lepidopterans, coleopterans, dipterans and hemipterans were reported to be 0.41, 0.25, 0.20, 0.21 and 0.18 visitors/m²/5-minute constituting 9.83, 6.06, 4.69, 5.10 and 4.29 per cent of the total visitors, respectively. The corresponding values for summer 2019 was 0.59, 0.27, 0.17, 0.21 and 0.17 visitors/m²/5 minute for stingless bees, lepidopterans, coleopterans, dipterans and hemipterans which constituted 10.18, 4.69, 2.96, 3.62 and 2.91 per cent of the total visitors, respectively. The mean activity of total visitors during 2018 was maximum at 10 00 h (13.13 visitors/m²/5 minute). The lowest activity of flower visitors was observed at 13 00 h (1.14 visitors/m²/5 minute). During summer 2019, the mean activity of flower visitors was maximum at 11 00 h (18.46 visitors/m²/5 minute) while it was lowest at 14 00 h (1.18 visitors/m²/5 minute). Maximum activity of *A. dorsata*, *A. cerana* and *A. florea* as well as stingless bee was observed at 11 00 h (2.71 bees/m²/5 minute), 10 00 h (6.11 bees/m²/5 minute), 10 00 h (1.74 bees/m²/5 minute) and 10 00 h (1.29 bees/m²/5 minute), respectively during summer 2018 whereas, minimum activity was observed at 13 00 h (0.11 bees/m²/5 minute), 16 00 h (0.14 bees/m²/5 minute), 14 00 h (0.03 bees/m²/5 minute) and 14 00 h (0.03 bees/m²/5 minute), respectively. During summer 2019, the activity of *A. dorsata*, *A. cerana* and *A. florea* as well as stingless bee were observed

maximum at 11 00 h (4.09 bees/m²/5 minute), 10 00 h (7.66 bees/m²/5 minute), 11 00 h (2.83 bees/m²/5 minute) and 11 00 h (1.91 bees/m²/5 minute), respectively while, minimum activity recorded at 14 00 h (0.23 bees/m²/5 minute), 13 00 h (0.34 bees/m²/5 minute), 14 00 h (0.23 bees/m²/5 minute) and 15 00 h (0.20 bees/m²/5 minute), respectively. Apart from bee species, the activities of lepidopterans, coleopterans, dipterans and hemipterans were found maximum at 11 00 h (0.69 visitors/m²/5 minute), 11 00 h (0.54 visitors/m²/5 minute), 11 00 h (0.51 visitors/m²/5 minute) and 11 00 h (0.49 visitors/m²/5 minute), respectively during summer 2018 whereas, minimum activity was observed at 13 00 h (0.11 visitors/m²/5 minute), 14 00 h (0.07 visitors/m²/5 minute), 13 00 h (0.14 visitors/m²/5 minute) and 13 00 h (0.09 visitors/m²/5 minute), respectively. During summer 2019, maximum activity of lepidopterans, coleopterans, dipterans and hemipterans was recorded at 10 00 h (0.60 visitors/m²/5 minute), 11 00 h (0.60 visitors/m²/5 minute), 11 00 h (0.66 visitors/m²/5 minute) and 11 00 h (0.43 visitors/m²/5 minute), respectively while, minimum activity was observed at 14 00 h (0.03 visitors/m²/5 minute), 13 00 h (0.09 visitors/m²/5 minute), 14 00 h (0.03 visitors/m²/5 minute) and 14 00 h (0.03 visitors/m²/5 minute), respectively.

The present finding on activities of honeybees is more or less similar with the earlier workers like Prakash (2002) ^[11], Deyto and Cervancia (2009) ^[4], Revanasidda and Belavadi (2019) ^[12]. They recorded *A. cerana* as the most abundant species on cucurbitaceous flowers in different regions. Patel (2022 a) ^[9], recorded maximum activity in week at 10 00 h on cucumber under cage condition plot. Patel (2022 b) ^[10] recorded maximum activity at 11 00 h during 2018 and on bitter gourd flowers in natural pollination with augmentation of *A. cerana* treatment plot.

Activity of different flower visitors on cucumber flowers in augmentation of *A. mellifera* to natural pollination

Among different flower visitors, the honeybees were the major visitors of bitter gourd flower during summer 2018 (70.02%) and summer 2019 (75.64%) of total visitors. Among different bee species, *A. cerana* was the predominant flower visitors (1.50 bees/m²/5 minute) constituting 36.13 per cent of total flower visitors which was followed by *A. dorsata* (0.88 bees/m²/5 minute) and *A. florea* (0.53 bees/m²/5 minute) which constituting 21.26 and 12.63 per cent of total flower visitors, respectively during summer 2018. During summer 2019, the maximum bee activity was exhibited by the *A. cerana* (2.29 bees/m²/5 minute) followed by *A. dorsata* (1.23 bees/m²/5 minute) and *A. florea* (0.84 bees/m²/5 minute) constituted 39.75, 21.29, and 14.60 per cent of total flower visitors, respectively. Apart from honeybees, the activity of stingless bees, lepidopterans, coleopterans, dipterans and hemipterans were reported to be 0.41, 0.25, 0.20, 0.21 and 0.18 visitors/m²/5-minute constituting 9.83, 6.06, 4.69, 5.10 and 4.29 per cent of the total visitors, respectively. The corresponding values for summer 2019 was 0.59, 0.27, 0.17, 0.21 and 0.17 visitors/m²/5 minute for stingless bees, lepidopterans, coleopterans, dipterans and hemipterans which constituted 10.18, 4.69, 2.96, 3.62 and 2.91 per cent of the total visitors, respectively. The mean activity of total visitors during 2018 was maximum at 10 00 h (13.13 visitors/m²/5 minute). The lowest activity of flower visitors was observed at 13 00 h (1.14 visitors/m²/5 minute). During summer 2019, the mean activity of flower visitors was maximum at 11 00 h (18.46 visitors/m²/5 minute) while it was lowest at 14 00 h

(1.18 visitors/m²/5 minute). Maximum activity of *A. dorsata*, *A. cerana* and *A. florea* as well as stingless bee was observed at 11 00 h (2.71 bees/m²/5 minute), 10 00 h (6.11 bees/m²/5 minute), 10 00 h (1.74 bees/m²/5 minute) and 10 00 h (1.29 bees/m²/5 minute), respectively during summer 2018 whereas, minimum activity was observed at 13 00 h (0.11 bees/m²/5 minute), 16 00 h (0.14 bees/m²/5 minute), 14 00 h (0.03 bees/m²/5 minute) and 14 00 h (0.03 bees/m²/5 minute), respectively. During summer 2019, the activity of *A. dorsata*, *A. cerana* and *A. florea* as well as stingless bee were observed maximum at 11 00 h (4.09 bees/m²/5 minute), 10 00 h (7.66 bees/m²/5 minute), 11 00 h (2.83 bees/m²/5 minute) and 11 00 h (1.91 bees/m²/5 minute), respectively while, minimum activity recorded at 14 00 h (0.23 bees/m²/5 minute), 13 00 h (0.34 bees/m²/5 minute), 14 00 h (0.23 bees/m²/5 minute) and 15 00 h (0.20 bees/m²/5 minute), respectively. Apart from bee species, the activities of lepidopterans, coleopterans, dipterans and hemipterans were found maximum at 11 00 h (0.69 visitors/m²/5 minute), 11 00 h (0.54 visitors/m²/5 minute), 11 00 h (0.51 visitors/m²/5 minute) and 11 00 h (0.49 visitors/m²/5 minute), respectively during summer 2018 whereas, minimum activity was observed at 13 00 h (0.11

visitors/m²/5 minute), 14 00 h (0.07 visitors/m²/5 minute), 13 00 h (0.14 visitors/m²/5 minute) and 13 00 h (0.09 visitors/m²/5 minute), respectively. During summer 2019, maximum activity of lepidopterans, coleopterans, dipterans and hemipterans was recorded at 10 00 h (0.60 visitors/m²/5 minute), 11 00 h (0.60 visitors/m²/5 minute), 11 00 h (0.66 visitors/m²/5 minute) and 11 00 h (0.43 visitors/m²/5 minute), respectively while, minimum activity was observed at 14 00 h (0.03 visitors/m²/5 minute), 13 00 h (0.09 visitors/m²/5 minute), 14 00 h (0.03 visitors/m²/5 minute) and 14 00 h (0.03 visitors/m²/5 minute), respectively.

The present finding on activities of honeybees is more or less similar with the earlier workers like Prakash (2002)^[11], Deyto and Cervancia (2009)^[4], Revanasidda and Belavadi (2019)^[12]. Kumar *et al.* (2015)^[7] recorded that the *A. mellifera* commenced its activity early in the morning and maximum abundance activity on cucumber during 09 00-10 00 h. The cessation of bee activity took place during 17 00-18 00 h. Patel (2022 b)^[10], recorded *A. mellifera* maximum activity at 10 00 h in flower visitors by *A. mellifera* on cucumber under cage condition plot.

Table 1: Relative abundance of pollinator fauna of cucumber during summer 2018 and summer 2019

Sr. No.	Pollinators	Order	Relative abundance of pollinators (%)					
			Natural pollination		Natural Pollination with augmentation (<i>A. cerana</i>)		Natural Pollination with augmentation (<i>A. Mellifera</i>)	
			2018	2019	2018	2019	2018	2019
1.	<i>A. dorsata</i>	Hymenoptera	18.22	13.70	15.05	5.42	7.85	2.50
2.	<i>A. cerana</i>	Hymenoptera	12.23	5.89	40.07	46.77	1.81	1.48
3.	<i>A. florea</i>	Hymenoptera	37.95	43.26	20.56	21.50	14.79	16.26
4.	<i>A. mellifera</i>	Hymenoptera	00	00	00	00	47.41	51.39
5.	Stingless bee	Hymenoptera	11.59	15.95	9.81	12.35	10.48	12.36
6.	Butterflies	Lepidoptera	6.32	6.33	4.76	4.40	5.81	4.87
7.	Coleopterans	Coleoptera	5.08	5.52	3.74	3.48	4.58	4.32
8.	Dipteran flies	Diptera	4.55	4.96	3.07	3.19	3.72	3.45
9.	Hemipteran bugs	Hemiptera	4.16	4.38	2.94	2.89	3.55	3.40

Table 2: Activity of different flower visitors on cucumber at different hours of the day in natural pollination treatment during summer 2018

Time (h)	*Mean number of visitors/m ² /5 min								Total
	<i>A. dorsata</i>	<i>A. cerana</i>	<i>A. florea</i>	Stingless bee	Lepidopterans	Coleopterans	Dipterans	Hemipterans	
06 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08 00	1.09	0.66	1.74	0.83	0.43	0.26	0.20	0.43	5.63
09 00	1.43	1.14	2.20	0.60	0.46	0.60	0.54	0.41	7.39
10 00	2.00	0.97	3.80	0.91	0.60	0.43	0.40	0.36	9.47
11 00	1.43	1.23	4.54	1.17	0.46	0.29	0.14	0.26	9.51
12 00	1.49	0.66	3.14	0.94	0.31	0.40	0.17	0.09	7.20
13 00	0.09	0.17	0.14	0.26	0.11	0.03	0.11	0.03	0.94
14 00	0.03	0.00	0.34	0.00	0.00	0.01	0.03	0.03	0.43
15 00	0.23	0.29	0.55	0.14	0.11	0.03	0.29	0.17	1.80
16 00	0.31	0.34	0.47	0.31	0.33	0.24	0.14	0.09	2.23
17 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean	0.62	0.42	1.30	0.40	0.22	0.17	0.16	0.14	3.43
Per cent	18.12	12.23	37.95	11.59	6.32	5.08	4.55	4.16	--

*Mean of seven weeks observations during flowering period of cucumber

Table 3: Activity of different flower visitors on cucumber at different hours of the day in natural pollination treatment during summer 2019

Time (h)	*Mean number of visitors/m ² /5 min								Total
	<i>A. dorsata</i>	<i>A. cerana</i>	<i>A. florea</i>	Stingless bee	Lepidopterans	Coleopterans	Dipterans	Hemipterans	
06 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08 00	0.71	0.60	1.74	0.80	0.37	0.23	0.20	0.37	5.03
09 00	1.11	0.54	2.54	0.60	0.38	0.40	0.46	0.44	6.47
10 00	1.26	0.31	4.37	1.46	0.51	0.43	0.34	0.23	8.91
11 00	1.23	0.29	4.66	1.77	0.69	0.69	0.46	0.49	10.26
12 00	1.17	0.29	3.80	1.23	0.23	0.34	0.14	0.06	7.26
13 00	0.00	0.11	0.14	0.29	0.11	0.03	0.09	0.03	0.80
14 00	0.03	0.00	0.37	0.29	0.00	0.01	0.03	0.03	0.75
15 00	0.11	0.23	0.55	0.14	0.11	0.03	0.29	0.17	1.63
16 00	0.29	0.17	0.50	0.31	0.33	0.24	0.14	0.09	2.06
17 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean	0.45	0.20	1.44	0.53	0.21	0.18	0.16	0.15	3.32
Per cent	13.70	5.89	43.26	15.95	6.33	5.52	4.96	4.38	--

*Mean of seven weeks observations during flowering period of cucumber

Table 4: Activity of different flower visitors on cucumber at different hours of the day in natural pollination with augmentation of *A. cerana* treatment during summer 2018

Time (h)	*Mean number of visitors/m ² /5 min								Total
	<i>A. dorsata</i>	<i>A. cerana</i>	<i>A. florea</i>	Stingless bee	Lepidopterans	Coleopterans	Dipterans	Hemipterans	
06 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08 00	1.11	2.34	1.26	1.00	0.40	0.54	0.26	0.51	7.43
09 00	1.29	4.66	2.00	0.97	0.69	0.49	0.49	0.36	10.94
10 00	2.86	6.60	3.20	1.34	0.63	0.66	0.20	0.35	15.83
11 00	2.51	8.17	3.29	1.91	0.40	0.31	0.34	0.29	17.23
12 00	2.20	5.46	4.09	1.29	0.54	0.40	0.23	0.16	14.36
13 00	0.37	0.63	0.40	0.34	0.23	0.00	0.11	0.11	2.20
14 00	0.29	0.37	0.23	0.00	0.03	0.18	0.03	0.03	1.15
15 00	0.49	1.11	0.30	0.23	0.26	0.08	0.31	0.09	2.87
16 00	0.37	1.23	0.93	0.40	0.46	0.20	0.37	0.34	4.30
17 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean	0.88	2.35	1.21	0.58	0.28	0.22	0.18	0.17	5.87
Per cent	15.05	40.07	20.56	9.81	4.76	3.74	3.07	2.94	--

*Mean of seven weeks observations during flowering period of cucumber

Table 5: Activity of different flower visitors on cucumber at different hours of the day in natural pollination with augmentation of *A. cerana* treatment during summer 2019

Time (h)	*Mean number of visitors/m ² /5 min								Total
	<i>A. dorsata</i>	<i>A. cerana</i>	<i>A. florea</i>	Stingless bee	Lepidopterans	Coleopterans	Dipterans	Hemipterans	
06 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08 00	0.43	2.63	1.26	1.00	0.40	0.51	0.23	0.49	6.94
09 00	0.57	5.37	2.23	1.14	0.63	0.49	0.46	0.34	11.22
10 00	1.06	7.74	3.51	1.66	0.49	0.60	0.17	0.30	15.53
11 00	0.63	9.46	3.91	2.46	0.60	0.34	0.63	0.43	18.46
12 00	1.09	6.80	3.86	1.97	0.40	0.31	0.17	0.16	14.76
13 00	0.26	1.23	0.54	0.63	0.20	0.00	0.11	0.09	3.06
14 00	0.00	0.43	0.23	0.11	0.03	0.18	0.03	0.03	1.04
15 00	0.17	1.23	0.30	0.29	0.23	0.08	0.31	0.09	2.69
16 00	0.03	1.57	0.91	0.37	0.46	0.20	0.37	0.34	4.26
17 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean	0.33	2.80	1.29	0.74	0.26	0.21	0.19	0.17	6.00
Per cent	5.42	46.77	21.50	12.35	4.40	3.48	3.19	2.89	--

*Mean of seven weeks observations during flowering period of cucumber

Table 6: Activity of different flower visitors on cucumber at different hours of the day in natural pollination with augmentation of *A. mellifera* treatment during summer 2018

Time (h)	*Mean number of visitors/m 2 /5 min									Total
	<i>A. dorsata</i>	<i>A. cerana</i>	<i>A. mellifera</i>	<i>A. florea</i>	Stingless bee	Lepidopterans	Coleopterans	Dipterans	Hemipterans	
06 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08 00	0.51	0.20	2.51	1.17	1.03	0.40	0.54	0.23	0.51	7.11
09 00	0.60	0.09	4.34	1.26	0.97	0.66	0.49	0.46	0.36	9.22
10 00	0.71	0.20	6.49	2.31	1.34	0.66	0.57	0.14	0.46	12.89
11 00	1.06	0.29	7.40	1.97	1.69	0.60	0.51	0.46	0.20	14.17
12 00	0.94	0.17	5.49	1.37	0.94	0.37	0.31	0.20	0.18	9.98
13 00	0.14	0.17	0.86	0.37	0.26	0.23	0.00	0.11	0.06	2.20
14 00	0.20	0.00	0.43	0.00	0.00	0.03	0.18	0.03	0.03	0.89
15 00	0.20	0.03	1.11	0.49	0.20	0.26	0.08	0.34	0.09	2.79
16 00	0.57	0.00	1.23	0.37	0.17	0.46	0.20	0.37	0.34	3.71
17 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean	0.38	0.09	2.30	0.72	0.51	0.28	0.22	0.18	0.17	4.84
Per cent	7.85	1.81	47.41	14.79	10.48	5.81	4.58	3.72	3.55	--

*Mean of seven weeks observations during flowering period of cucumber

Table 7: Activity of different flower visitors on cucumber at different hours of the day in natural pollination with augmentation of *A. mellifera* treatment during summer 2019

Time (h)	*Mean number of visitors/m 2 /5 min									Total
	<i>A. dorsata</i>	<i>A. cerana</i>	<i>A. mellifera</i>	<i>A. florea</i>	Stingless bee	Lepidopterans	Coleopterans	Dipterans	Hemipterans	
06 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08 00	0.26	0.11	2.69	1.20	0.94	0.40	0.54	0.23	0.54	6.91
09 00	0.29	0.17	5.20	1.40	1.14	0.60	0.49	0.34	0.34	9.96
10 00	0.31	0.23	7.17	2.54	1.74	0.51	0.57	0.20	0.46	13.75
11 00	0.23	0.31	8.60	2.74	2.17	0.49	0.51	0.54	0.26	15.86
12 00	0.20	0.11	6.40	1.91	1.66	0.37	0.34	0.14	0.18	11.33
13 00	0.03	0.06	1.46	0.34	0.29	0.23	0.00	0.11	0.06	2.57
14 00	0.09	0.00	0.29	0.00	0.00	0.03	0.18	0.03	0.03	0.64
15 00	0.17	0.00	1.14	0.49	0.26	0.23	0.08	0.34	0.09	2.79
16 00	0.11	0.00	1.74	0.34	0.14	0.43	0.20	0.37	0.34	3.69
17 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18 00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean	0.13	0.08	2.67	0.84	0.64	0.25	0.22	0.18	0.18	5.19
Per cent	2.50	1.48	51.39	16.26	12.36	4.87	4.32	3.43	3.40	--

*Mean of seven weeks observations during flowering period of cucumber

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