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Insect Visitors on Cucumber and Bittergourd Flowers and Impact on Quantity of Crop Production by Different Pollination Treatment

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Abstract

Studies were conducted to determine diversity and abundance of pollinator fauna and their role on cucumber and Bittergourd production. The studies revealed that cucumber flowers attracted wide varieties of insects belonging to 4 orders, 12 families, 17 genera and 21 species. Of all these insects, honeybees were the most predominant and comprised more than 74 percent of the total flower visiting insects. There abundance was in the order *Apis mellifera* > *A. cerana* > *A.dorsata* > *A. florea*. The other important insects visiting cucumber flower were *Xylocopa fenestrata, X. pubescens, Pithitus smaragdula, Halictus* spp., *Lasioglosium* spp., *Anthophora* spp. and *Andrena* spp. which collected nectar and pollen and constituted important pollinators of cucurbits. Bittergourd flowers also attracted a large number of insects belonging to 4 orders, 10 families, 11 genera and 13 species. In case of bittergourd also, honeybees such as *A. mellifera, A. dorsata* and *A. cerana* were the most important pollinators which comprised more than 69% of the total flower visiting insects. Observation on diurnal pattern of flower visiting insects revealed that in case of cucumber, maximum population of *A. mellifera* was observed between am 09:00-10:00 when relative humidity was 76%, temperature 34°C, nectar sugar concentration 34.5%, solar radiation 36mW/cm^2 and light intensity 40 lx. Another peak was observed in the evening between pm 16:00-17:00 when the relative humidity was 68 percent, temperature 36°C, nectar sugar concentration 36%, solar radiation 42mW/cm^2 and light intensity 28 lx. A similar pattern was observed in Bittergourd also. Studies on seasonal pattern revealed that in cucumber and bittergourd flowers insect visitation increased during different weeks commencing from first week to 9th week and declined thereafter. The correlation coefficient between different flower visiting insects and weather parameters revealed that relative humidity, rainfall and minimum temperature had a negative influence on visitation pattern of bee species and other insects. However, maximum temperature had a pronounced effect on the popul ation of these bees which increased with the temperature. Mean evaporation had a positive effect on *A. dorsata, A. cerana* and *Xylocopa* species whereas negative effect on *A. mellifera*. The studies revealed that percentage fruit set varied in different treatments. In case of bee pollination, fruit set was significantly higher (84.14%) followed by hand pollination (76%) and open pollination (74.76%).

Key words: Cucumber, Bittergourd, Pollinator diversity, Bees, Weather parameters, Fruit set

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INTRODUCTION

Cucurbits form an important and vast group of vegetable crops cultivated extensively in India. Of the several vegetables, cucumber and bittergourd are important crops. Cucumber (*Cucumis sativas* L.) and Bittergourd (*Memordica charantia* L.) belonging to Cucurbitaceae are highly cross pollinated as pollen grains being sticky and large in size, need an agent to transfer to the pistillate flowers for fruit set. Furthermore, reproductive organs of male and female flowers occur separately on staminate and pistillate flowers which necessitate the services of pollinating insects. Among the pollinating insects, the honey bees are known to be the most efficient pollinating agents of cucumber and bittergourd (Grewal and Sidhu, 1979). Diversity of pollinating insects has been reported to vary in different locations. For instance, Girish (1981) reported that *A. cerana, A. dorsata* and *A. florea*, were the most important pollinators of summer squash around Bangalore and contributed 87, 10 and 3 percent, respectively. Mohan Rao and Suryanarayana (1988) in Vijayarai (Andhra Pradesh, India) observed honey bees, solitary bees and few dipterans visiting watermelon flowers. Of the honey bee species, *A. cerana* (87%) was found to be more efficient pollinator than *A. florea* and *Tetragonula iridipennis*. Cervancia and Bergonia (1990) in Philippines reported that *Xylocopa chlorine, X. philippinesis, Megachile atrata* and *A. dorsata* were the frequent visitors of pickling cucumber flowers. Shrivastava and Shrivastava (1991) in Rewa (India) recorded 23 species of insects visiting cucurbitaceous crops. Sihag (1993) recorded *Xylocopa fenestrata* visiting white flower gourd/bottle gourd (*Lagenaria ciceraria* (Mol.) Standl.) for pollen and nectar and acted as a good pollinator. Cucumber crop was visited by 27 insect species, of which 16 belonging to Hymenoptera and four each to Diptera, Lepidoptera and Coleoptera. The hymenopterans *viz., A. dorsata, A. cerana, A. florea* and *T. iridipennis* comprised more than 82 percent of the total insect pollinators (Prakash, 2002). Both cucumber and bittergourd has been reported to benefit greatly from insect pollination. Kauffeld *et al*. (1975) reported that honey bee pollination increased the average weight and quality of cucumbers both in open and plots caged with honey bees. Nidagundi (2004) reported that significantly highest length of fruits and weight was obtained in bittergourd in open pollinated as compared to caged plot without bees. In a similar study, Behera *et al*. (2010) suggested that for a commercial fruit and seed production in bittergourd (*Memordica*). pollination management is essential.

Similar information on the pollinating insects of cucumber and bittergourd from Jammu, India is relatively unknown. Evidently, the need was felt to explore the pollinating agents and their role in production of cucumber and bittergourd.

MATERIALS AND METHODS

The present investigation was carried out in the experimental farm of Division of Entomology, Sher-e-Kashmir university of Agricultural Sciences & Technology main campus Chatha, Jammu located 10kms from Jammu city. The study was made on crop raised in the month of February, 2011-12. The crop was raised in a plot size of 5 x 5m following package of practices. The details of various materials used and methods employed for achieving the objectives of the present investigation are given under the following heads.

Abundance of insect pollinator on cucumber and bittergourd

Observations were made for different groups of pollinator visiting the cucumber (*Cucumis sativa* L.) and bittergourd (*Memordica charantia* L.) field during flowering at 09:00-10:00, 13:00-14:00 and 16:00-17:00 for five minutes in each square meter area from five plants during peak flowering period. Honey bee species visiting flowers were identified in the field itself whereas other pollinator were collected, pinned, labeled and identified. The data were later grouped order wise to infer the

abundance of pollinators. Simultaneously, abiotic and biotic parameters such as relative humidity, temperature, light intensity, solar radiation, wind velocity and nectar sugar concentration were recorded to determine their influence on pollinator abundance. Relative abundance of dominant species of pollinator was worked out by using the following formula after pooling all the data and expressed in percentage.

$$\text{Relative abundance of species A (\%)} = \frac{\text{Number of species A}}{\text{Total number of pollinators}} \times 100$$

Role of insect pollination on quantity of fruit production

This study was made in Rabi season of 2011-12 and crop was raised in a plot size of 5x5m following package of practices. To determine, the impact of pollinators on quantity of fruit production, the studies were made under open pollination, hand pollination, bee pollination and self-pollination (Table 1). The experiment was carried out in RBD with four treatments replicated thrice.

All the treatments were imposed at 10 percent flowering of the crop. In open pollination (T1), pollinators had unrestrained access on flowers, whereas in hand pollination pollen from flowers was emasculated on other flowers (T2). In bee pollination (T3), a colony of bee was kept in cage to ensure pollination. Bee hive with back and front entrance was kept open in one boundary of cage to facilitate the bees to move in and out either inside or outside the cage and in self pollination, flowers were caged with synthetic nylon netting to exclude nectarivorous insects (T4). The cage was removed after completion of flowering. After maturity, the crop was harvested and compared for different treatments. In order to evaluate the role of insect pollination in enhancing the productivity and quality of cucumber and bitter gourd, the following quantitative and qualitative parameters were recorded from each treatment.

Table 1. Different pollination treatments used in the study

S. No	Treatment
T1	Open pollination.
T2	Hand pollination.
T3	Bee pollination (Crop caged with bees)
T4	Self pollination

Number of fruit in each plant

In each treatment, five plants were selected randomly. The numbers of fruits in each plant were counted and mean number of fruits per plant was calculated.

Rate of fruit set

The fruit set in all the treatments was estimated by counting the number of fruit set out of female flowers. The mean fruit set was expressed as given below:

$$\text{Rate of fruit set (\%)} = \frac{\text{Number of fruit set}}{\text{Total number of female flower}} \times 100$$

Statistical analysis

Experiments were set up as complete randomized design. Data were analyzed using one-way analysis of variance (ANOVA), and Fisher least significant difference (LSD) test was performed to make pairwise comparisons among treatment means (at a significance level of α=0.05 and 0.01). The means and standard deviations of each variable were calculated. All calculations were performed using the MS Exel and Statistical software. Correlation coefficient analysis was performed using the methods described by Sokal and Rholf (1981).

RESULTS

The results of the present investigations carried out on pollinator diversity, their abundance and role on quantity of fruit production are given below:

Abundance and diversity of insect pollinators

Cucumber flowers attracted wide variety of insect

Table 2. Taxonomic status of insect species visiting cucumber and bittergourdflowers

Cucumber (*Cucumis sativus*)					
Sl. No.	Taxon			Common name	Insects abundancy (%)
	Order	Family	Species		
1	Hymenoptera	Apidae	*Apis mellifera*	European bees	47.52
			Apis dorsata	Rock bees	5.38
			Apis cerana	Indian bees	20.59
			Apis florea	Little bees	0.37
		Xylocopidae	*Xylocopa fenestrata*	Carpenter bees	0.92
			Xylocopa pubescens		
		Anthophoridae	*Pithitus smargdula*	Ceratina	2.60
		Halictidae	*Halictus* spp.	Sweat bee	1.80
			Lasioglosium spp.		1.49
		Andrenidae	*Andrena* spp.		0.85
2	Diptera	Syrphidae	*Metasyrphus corolla*		2.21
			Eristalis spp.		2.31
			Sporophoria Indiana	Syrphid flies	2.16
			Eratalis tenax		1.85
			Episyrphus balteatus		1.72
		Muscidae	*Musca* spp.	Housefly	2.00
		Sarcophagidae	*Sarcophagi* spp.	Flesh fly	0.17
3	Lepidoptera	Papilionidae	*Papilio demoleus*		0.68
		Lycaenidae	*Junomia* spp.	Butterflies	1.36
4	Coleoptera	Coccinellidae	*Coccinella septem*	Ladybird beetle	1.21
Bittergourd (*Memordica charantia*)					
Sl. No.	Taxon			Common name	Insects abundancy (%)
	Order	Family	Species		
1	Hymenoptera	Apidae	*Apis mellifera*	European bee	43.2
			Apis dorsata	Rock bee	7.09
			Apis cerana indica	Indian bee	18.9
		Xylocopidae	*Xylocopa* spp.	Carpenter bee	0.75
		Anthophoridae	*Pithitus smargdula*		8.86
		Halictidae	*Halictus* spp.	Sweet bee	5.75
		Andrenidae	*Andrena* spp.		2.95
2	Diptera	Syrphidae	*Episyrphus balteatus*		3.36
			Metasyrphus corolla	Syrphid flies	2.54
		Muscidae	*Musca* spp.	Housefly	1.50
3	Lepidoptera	Pieridae	*Pieris rapae*		1.63
		Papilionidae	*Eurytides Marcellus*	Butterflies	1.52
4	Coleoptera	Coccinellidae	*Coccinella septumpunctata*	Lady bird beetle	1.94

belonging to four orders, 12 families, 17 genera and 21 species (Table 2). Of all these insects, honeybees were the most predominant and comprised more than 74% of the total flower visiting insects. Among the honeybees, *Apis mellifera* was the most common (47.52%) followed by *A. cerana* (20.59%) and *A. dorsata* (5.38%). *A. florea* was the least abundant comprising 0.37% only. In general, there abundance was in the order *A. mellifera* >*A. cerana* >*A. dorsata* >*A. florea*. The other important insects visiting cucumber flowers were *Xylocopa fenestrata*, *X. pubescens*, *Pithitus smargdula, Halictus* spp., *Lasioglosium* spp., *Anthophora* spp. and *Andrena* spp. which collected nectar

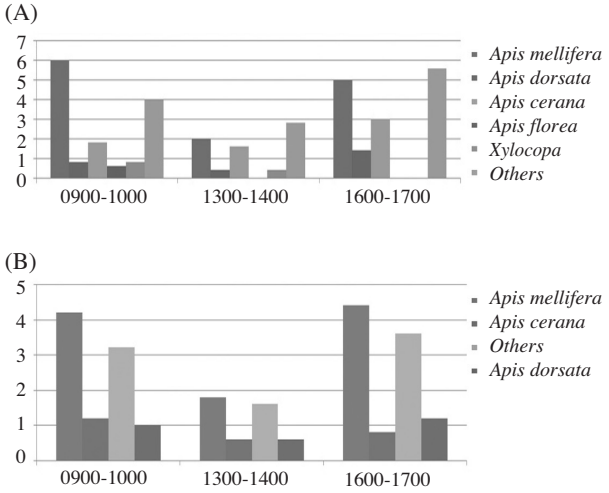

Fig. 1. Foraging Activity of insect pollinators on cucumber (A) and bittergourd (B) flowers.

and pollen and constituted important pollinators of cucurbits. The other insects such as *Metasyrphus corollae, Eristalis* spp., *Sporophoria indiana*, *Eristalis tenax*, *Musca* spp., *Sarcophagi* spp., Butterflies and *Coccinela septumpunctata* mostly collected nectar and were observed at interrupted hours. Of all flower visiting insects, honeybees which visited cucumber flowers throughout the day in large number and collected nectar and pollen were considered as the most important pollinators. In case of Bittergourd flowers also (Table2) a large number of insects belonging to 4 orders, 10 families, 11 genera and 13 species were observed. Of all these insects, honeybees such as *A. mellifera*, *A. dorsata* and *A. cerana* were the important pollinators which comprised more than 69.19% of the total flower visiting insects. *A. florea* was not observed visiting Bittergourd flowers. The abundance of honeybee species was in the order *A. mellifera* >*A. cerana* >*A. dorsata*. The other important flower visitors were *P. smargdula, Xylocopa* species*, Halictus* species, *Andrena* species, Syrphids, *Musca* species, Butterflies and Coccinellids. In this crop also, honeybees were categorized as the most important pollinators. The distribution pattern of different insects visitor in terms of the proportion on cucumber is depicted in figure 1(A) and on Bittergourd figure 1(B). It is evident from the above studies that in both crops such as cucumber and bittergourd, honeybees constitute a predominant group of insects and are efficient pollinators. The other insects which frequented in few number at interrupted hours plays supplementary role in the pollination of above said crops.

Diurnal pattern of insect visitors on cucurbits

Observations recorded at two hour interval from 09:00-17:00 times to determine the pattern of insect visitors on these crops during different hours of the day revealed that in case of cucumber, maximum population of *A. mellifera* was observed during early times of the day i.e 09:00-10:00 when a relative humidity was 76%, temperature 34°C, nectar sugar concentration 34.5%, solar radiation 36mW/cm^2 and light intensity 40 lx The population was low during mid hours of the day i.e. 13:00-1400 when the RH was 64%, temperature- 37.5°C, NSC -38, SR-54mW/cm^2 and light intensity-54 lx. In the afternoon, again the population increased between 16:00-17:00 when the relative humidity was 68%, temperature 36°C, nectar sugar concentration 36%, solar radiation 42mW/cm^2 and light intensity 28 lx. Similar pattern was observed in case of *A. dorsata* and *A. cerana* though there population was very low. The other flower visitors such as *A. florea*, *X. fenestrata, X. pubescens* did not follow a particular pattern and their population was very low. Similarly, on other days of observation, the populations of these species fluctuated during different times depending upon the climatic condition prevailing during different days. However, the decline in population during mid day was observed during all the days of observation. In Bittergourd also, maximum population of *A. mellifera* was observed during early times of the day (09:00-10:00 hrs) and late times of the day (16:00-17:00) with a dip in population during mid- day (13:00-14:00). Similar trend was observed on all the days of observation. The decline in population of bees during mid day may possibly due to physiology of the plant or availability of floral rewards and climatic conditions.

Seasonal pattern of visitation of insects on cucurbit flowers

Weekly observations recorded at three different times 09:00-10:00, 13:00-14:00 and 16:00-17:00 for different

Table 3. Population dynamics of insect pollinators on cucumberand bittergourdflowers on different days of observation during different times of the day

Observation (Hours)	*Apis mellifrea*	*Apis dorsata*	*Apis cerana*	*Apis florea*	*Xylocopa fenestrata*	*Xylocopa pubescens*	Others	RH	TMP	NSC	SR	LI
Cucumber												
Insect pollinators/5 plants /5min												
23 May 2011												
09:00-10:00	6.00	0.80	1.80	0.60	0.40	0.40	4.00	76	34	34.5	36	40
1300-1400	2.00	0.40	1.60	0.00	0.20	0.20	2.80	64	37.5	38.0	54	54
1600-1700	5.00	1.40	3.00	0.00	0.00	0.00	5.60	68	36	36.0	42	28
Total	13.0	2.60	6.40	0.60	0.60	0.60	12.4					
24 May 2011												
0900-1000	5.80	2.20	2.60	0.20	0.60	0.60	5.20	74	33	36.0	42	34
1300-1400	2.20	1.00	2.00	0.00	0.00	0.00	3.60	66	39	40.5	64	70
1600-1700	6.00	1.40	2.40	0.20	0.60	0.40	6.00	67	37	39.0	52	32
Total	14.0	4.60	7.00	0.40	1.20	1.00	14.8					
25 May 2011												
0900-1000	6.00	0.80	2.40	0.00	0.40	0.40	5.80	68	34	32.5	38	44
1300-1400	3.00	0.80	1.80	0.00	0.00	0.20	2.00	57	38	36.0	62	74
1600-1700	5.40	1.00	3.80	0.20	0.60	0.20	5.20	58	37	35.0	43	36
Total	14.4	2.60	8.00	0.20	1.00	0.80	13.0					
26 May 2011												
0900-1000	5.40	0.60	2.80	0.40	0.20	0.20	6.00	62	33	34.0	46	44
1300-1400	3.00	0.80	1.40	0.00	0.00	0.00	2.60	50	37	36.0	62	72
1600-1700	8.00	0.60	3.60	0.20	0.00	0.20	7.00	52	36	35.5	58	28
Total	16.4	2.00	7.80	0.60	0.20	0.40	15.6					
27 May 2011												
0900-1000	7.20	1.40	1.60	0.00	0.00	0.60	4.00	64	34	30.0	36	50
1300-1400	1.80	1.00	1.40	0.00	0.00	0.00	2.80	56	38	33.0	54	78
1600-1700	6.20	1.80	3.20	0.40	0.00	0.00	5.60	58	37	32.5	42	34
Total	15.2	4.20	6.20	0.40	0.00	0.60	12.40					
30 May 2011												
0900-1000	6.60	1.20	1.80	0.20	0.40	0.00	5.00	66	36	31.0	39	54
1300-1400	2.00	0.80	1.20	0.00	0.00	0.00	3.40	52	40	34.5	60	76
1600-1700	7.00	1.40	4.00	0.20	0.20	0.20	6.00	60	38	33.0	48	38
Total	15.60	3.40	7.00	0.40	0.60	0.20	14.40					
Bittergourd												
Insect pollinators/5 plants /5min												
23 May 2011												
0900-1000			4.20	1.00	1.20	0.00	3.20	76	34	34.5	36	40
1300-1400			1.80	0.60	0.60	0.00	1.60	64	37.5	38.0	54	54
1600-1700			4.40	1.20	0.80	0.00	3.60	68	36	36.0	42	28
Total			10.4	2.80	2.60	0.00	8.40					
24 May 2011												
0900-1000			4.00	0.80	1.00	0.00	4.00	74	33	36.0	42	34
1300-1400			2.00	0.00	0.40	0.00	2.00	66	39	40.5	64	70
1600-1700			4.60	1.20	1.80	0.00	3.20	67	37	39.0	52	32
Total			10.6	2.00	3.20	0.00	9.20					
25 May 2011												
0900-1000			4.60	1.00	1.40	0.00	5.20	68	34	32.5	38	44
1300-1400			2.40	0.20	0.00	0.00	1.20	57	38	36.0	62	74
1600-1700			5.20	1.20	2.00	0.00	5.00	58	37	35.0	43	36

Table 3. Continued

Bittergourd												
Insect pollinators/5 plants /5min												
Observation (Hours)	*Apis mellifrea*	*Apis dorsata*	*Apis cerana*	*Apis florea*	*Xylocopa fenestrata*	*Xylocopa pubescens*	Others	RH	TMP	NSC	SR	LI
Total			12.2	2.40	3.40	0.00	11.4					
26 May 2011												
0900-1000			4.60	1.20	2.00	0.00	5.00	62	33	34.0	46	44
1300-1400			1.60	0.40	0.60	0.00	1.00	50	37	36.0	62	72
1600-1700			4.20	1.00	2.20	0.00	5.20	52	36	35.5	58	28
Total			11.4	2.60	4.80	0.00	11.2					
27 May 2011												
0900-1000			4.60	1.00	1.20	0.00	4.00	64	34	30.0	36	50
1300-1400			1.40	0.60	0.40	0.00	1.60	56	38	33.0	54	78
1600-1700			5.60	1.60	2.00	0.00	4.60	58	37	32.5	42	34
Total			11.6	3.20	3.60	0.00	10.2					
30 May 2011												
0900-1000			4.60	0.60	1.00	0.00	4.00	5.00	66	36	31.0	39
1300-1400			2.00	0.20	0.60	0.00	2.20	3.40	52	40	34.5	60
1600-1700			5.00	0.80	1.40	0.00	4.60	6.00	60	38	33.0	48
Total			11.6	1.60	3.00	0.00	10.8					

days on the insects visiting cucurbits to determine the seasonal pattern of flower visitation revealed that insect visitation increased during different weeks commencing from first week to 9th week and declined thereafter. In case of *A. mellifera*, the population observed during different weeks increased from 73.4 (first week) to 108.0 (9th week) and declined thereafter and was observed to be 85.8 during 11th week. However, in case of other bees, the population trend did not follow the same pattern as in case of *A. mellifera*. In case of *A. dorsata*, the population increased from first week to IVth week and declined thereafter. Similarly, in case of *Apis cerana* also, population increased from first week to IVth week and then started declining. In case of bittergourd also, as in case of cucumber, *A. mellifera* population increased from first week to 8th week and then declined thereafter. In case of *A. dorsata*, no uniform pattern was observed. Population increased during some weeks and then declined and again increased thereby following irregular pattern. Similar was true in case of *A. cerana* visiting Bittergourd flowers.

Relationship between insect visitors and environmental parameters

The correlation coefficient between different bee species visiting cucumber flowers in relation to environmental factors is presented in Table 3. The data revealed that relative humidity, rainfall and minimum temperature had a negative influence on visitation pattern of different bee species and other insects. However, maximum temperature had a pronounced effect on the population of the bees which increased with the temperature. Mean evaporation had a positive effect on *A. dorsata*, *A. cerana* and *Xylocopa* species whereas negative and non-significant effect was observed on *A. mellifera*. In case of bittergourd, similar trend was observed in case of *A. mellifera*, *A. dorsata* and *A. cerana* and other insects with rainfall, humidity and minimum temperature. However, relationship with maximum temperature was positive and its significance varied from one species to another. Mean evaporation positively influenced the activities of *A. dorsata*, *A. cerana* and other insects and was negatively correlated with population abundance of *A. mellifera*.

Table 4. Correlation coefficient matrix exhibiting interrelations of different environmental factors influencing pollination activity of insects visiting *Cucumis sativus* L. and *Memordica charantia* flowers

Cucumber						
	Apis mellifera	*Apis dorsata*	*Apis cerana*	*Apis florea*	*Xylocopa* spp.	Others
RF	- 0.314*	- 0.879**	- 0.666*	- 0.489	- 0.392	- 0.489*
RH1	- 0.315*	- 0.852**	- 0.677*	- 0.260	- 0.355	-0.603**
RH2	0.356*	- 0.909**	- 0.671*	- 0.442*	- 0.413	-0.749**
Max temp	0.623*	0.847**	0.616*	0.371*	0.344	0.644*
Min temp	0.394	- 0.660*	- 0.495	- 0.621*	- 0.708*	- 0.722*
Mean Evaporation	- 0.387	0.931**	0.727*	0.296	0.334	0.483

Bittergourd				
	Apis mellifera	*Apis dorsata*	*Apis cerana*	Others
RF	- 0.512	- 0.200**	- 0.324	- 0.381
RH1	-0.447	- 0.377	- 0.330**	- 0.466
RH2	0.615*	- 0.338*	- 0.299	- 0.641*
Max temp	- 0.609*	0.361	0.307*	0.538
Min temp	0.337	- 0.022	- 0.112	- 0.637*
Mean evaporation	- 0.571	0.495	0.333	0.377

*Significant P<0.05, **Significant P<0.01

Impact of pollination treatments on quantity of fruit set in cucumber

The data presented in Table 5 revealed that percentage fruit set varied in different treatments. In case of bee pollination, fruit set was significantly higher (84.1%) followed by hand pollination (76%) followed by open pollination (74.8%). All these treatments were superior over self pollination where fruit set was only 22.5%. The data clearly shows that bee pollination resulted in higher fruit set followed by hand pollination and open pollination as compare to self pollination. Similarly, the percentage increased over control was much higher in bee pollination as compare to other treatments. In case of bittergourd also, bee pollination was most effective resulting in higher percentage of fruit set (87.1%) as compare to self pollination (2.7%). In general, the overall effectiveness of treatments was in the order: Bee pollination > hand pollination > open pollination > self pollination.

DISCUSSION

The results of the present investigations carried out on pollinator fauna, role of insect pollination on cucumber and Bittergourd yield are discussed under the following heads.

Diversity of insect pollination

The studies revealed that cucumber flowers attracted wide variety of insects belonging to four orders, 12 families, 17 genera and 21 species (Table 2). Of all these insects, honeybees were the most predominant and comprised more than 73.9% of the total flowers visiting insects. Similarly in Bittergourd also honeybees such as *A. mellifera*, *A. dorsata* and *A. cerana* were the important pollinators which comprised more than 69.2% of the total flower visiting insects. It is evident from the above studies that in both the crops honeybees constituted a predominant group of insects were efficient pollinators. In earlier studies also, honey bees (Roubik, 1995) and halictids (Grewal and Sidhu, 1978) have been reported as the principal pollinators of cucurbits in tropical America and India, respectively. In a similar study, Prakash (2002) reported that the cucumber crop was visited by 27 insect species, of which 16 belonged to Hymenoptera and four each to Diptera, Lepidoptera and Coleoptera. The hymenopterans *viz*., *A. dorsata*, *A. cerana*, *A. florea* and *T. iridipennis* comprised more than 82% of the total insect pollinators.

Table 5. Impact of pollination treatments on quantity of fruit set in cucumber and bittergourd

Sl. No.	Treatments	Percent fruit set	Percent increases over control (Self pollination)
		Cucumber	
1	Hand Pollination	76.00	237.3
2	Self Pollination	22.53	-
3	Bee Pollination	84.14	273.4
4	Open Pollination	74.76	231.8
		Bittergourd	
1	Hand Pollination	60.32	190.9
2	Self Pollination	20.73	-
3	Bee Pollination	87.14	320.3
4	Open Pollination	65.21	214.5

Nidagundi (2004) reported that among the 10 species of pollinators in bittergourd, *A. florea* was the most predominant constituting 43% of the total pollinators, followed by *A. cerana* (26%), *A. dorsata* (13%) and other pollinators (18%). Baker (1983) also and showed that hymenoptera is the most important order of anthophilous insects visiting cucumber flowers.

Diurnal pattern of insect visitors on cucurbits

The studies on diurnal pattern of insects visiting cucumber and Bittergourd revealed that maximum population of *A. mellifera* was observed during early times of the day i.e. 09:00-10:00 when RH was 76%, temperature 34°C, NSC(nectar sugar concentration) 34.5%, solar radiation 36mW/cm2 and light intensity 40 lx and in the evening between 16:00-17:00 when the RH was 68%, temperature 36°C, NSC 36%, solar radiation 42mW/cm^2 and light intensity 28 lx. The population was low during mid times of the day i.e. 13:00-14:00 when the RH was 64%, temperature 37.5°C, NSC 38%, SR 54mW/cm^2 and light intensity 54 lx.

Similar pattern was observed in case of *A. dorsata* and *A. cerana* though there population was very low. The other flower visitors such as *A. florea*, *X. fenestrata*, *X. pubescens* were very low in numbers and their population did not follow a particular pattern. In Bittergourd also, maximum population of *A. mellifera* was observed during early (09:00-10:00) and late times of the day (16:00-17:00) with a dip in population during mid-day (13:00-14:00). Different investigators have recorded different timing of initiation of activity of pollinators, its peak and cessation depending upon different locations and environmental conditions. For instance, Bhambure (1958) recorded that *A. cerana*, *A. florea* and *Melipona* sp. started collection of pollen from watermelon at AM 08:30 and their activity reached the peak at 10:30. *A. cerana* deserted the crop every day by 12:00, but *A. florea* continued to work till sunset in Bombay. Sanduleac (1959) in Rumania observed that honey bees worked on the cucurbit flowers (*Cucurbita pepo* L., *C. maxima* D. and *C. moschata* Duch ex Poir.) most intensively from 06:00 to 12:00 with a maximum activity from 08:00 to 09:00. Honeybees worked on the staminate flowers more vigorously than the pistillate flowers. Rao and Suryanarayana (1988) stated that *A. cerana* was the principal pollinating insect and found to be efficient pollinator than *A. florea* and *T. iridipennis*. Cervancia and Bergonia (1990) reported that common flower visitors of cucumber such as *A. dorsata F, Xylocopa chlorinae*, *X. philippiinensis* Smith, *Megachile atrata* Smith were most abundant from 10:00 h to 11:00. Sattigi *et al*. (1996) reported that in general foraging activity of honey bees was noticed throughout the day, but it was at its peak between 08:00 to 11:00 in winter, 06:00 to 11:00 and 16:00 to 18:00 in summer and 08:00 to 12:00 in monsoon irrespective of the crops in transitional area. The foraging activity was low during other hours of the day in different seasons.

Seasonal pattern of visitation of insects on cucurbit flowers

Weekly observations made at three different times 09:00-10:00, 13:00-14:00 and 16:00-17:00 revealed that insect visitation increased during different weeks commencing from first week to 9th week and declined thereafter (Table 3). In case of *A. mellifera*, the population observed during different weeks increased from 73.4 (first week) to 108.0 (9th week) and declined thereafter (85.8, 11th week). However, in case of other bees, the population trend did not follow the same pattern as in case of *A. mellifera*. In case of *A. dorsata*, the population increased from first week to 4th week and declined thereafter. Similarly, in case of *A. cerana* also population increased from first week to 4th week and then started declining.

In case of bittergourd as in case of cucumber, *A. mellifera* population increased from first week to 8th week and then declined thereafter. In a similar study, Pandian *et al*. (2012) reported that activity of *A. florea, A. cerana indica, A. femoralis* and *C. compressus* was observed to begin around 07:00 hrs and ceased around 18:00 hrs on cloudy days. Activity of these insects was found to be high from 0800 hrs to1000 hrs when the temperature ranged from 25-32°C and relative humidity 81-85%. The activity of these insects was found to decline after 1400 hrs, when the temperature ranged from 24-34°C and relative humidity 67-86%. They further found that on sunny days, activity of these insects was found to be high from 0900 hrs to 1000 hrs, when the temperature ranged from 27-30°C and relative humidity 75-83%. Activity of these insects was found to decrease after 1500 hrs, when temperature ranged from 23-34°C and relative humidity 69-78%. However, on rainy days, the activity of these insects was found to be high from 0800 hrs to 1200 hrs when the temperature ranged from 24-30°C and relative humidity was 75-83%. Activity of these insects was found to decrease after 1300 hrs, when temperature ranged from 27-33°C and relative humidity was 69-80%. The observed variations between present study and those reported by Pandian *et al*. (2012) may be due to different climatic conditions, crop studied, geographic location and species specific differences.

Relationship between insect visitors and environmental parameters

The data presented in Table 4 revealed that relative humidity, rainfall and minimum temperature had a negative influence on visitation pattern of different bee species and other insects. However maximum temperature had pronounced effect on population of the bees which increased with the temperature. Mean evaporation had a positive effect on *Apis dorsata*, *Apis cerana* and *Xylocopa* species and negative effect on *Apis mellifera*. However, the relationship with *Apis mellifera* was non-significant. In case of Bittergourd (Table 4) similar trend was observed in case of *Apis mellifera*, *Apis dorsata* and *Apis cerana* and other insects with rainfall, humidity and minimum temperature. However, relationship with maximum temperature was positive and its significance varied from one species to another. Mean evaporation positively influenced the activities of *Apis dorsata*, *Apis cerana* and other insects and was negatively correlated with population abundance of *A. mellifera*. Pandian *et al*. (2012) reported that the foraging activity of insect visitors showed negative correlation with temperature and positive correlation with relative humidity on cloudy and sunny days. Benedek and Prener (1972) found that air temperature significantly affected the foraging activities of honeybees. They further reported that flower visiting rate increased with increasing air temperature. Cirudarescu (1971) found that the number of insect visitors on lucerne varied directly with temperature and inversely with relative humidity.

Impact of pollination treatments on quantity of fruit set in cucumber

The studies revealed that (Table 5) that percentage fruit set varied in different treatments. In case of bee pollination, fruit set was significantly higher (84.14%) followed by

hand pollination (76%) followed by open pollination (74.76%). All these treatments were superior over self pollination where fruit set was only 22.5%. The data clearly shows that bee pollination resulted in higher fruit set followed by hand pollination and open pollination as compared to self pollination. Similarly, the percentage increased over control was much higher in bee pollination as compare to other treatments. In case of bittergourd also, bee pollination was most effective resulting in higher percentage of fruit set (87.14) as compare to self pollination (2.73%). The other treatments were in between the two, similarly percentage increased over control was much higher in bee pollination (320.3%). In general, the overall effectiveness of treatments was in the order Bee pollination > hand pollination > open- pollination > self pollination. Similar results have earlier been obtained by several investigators who reported tremendous increases in quantity as well as quality of the crop. Kauffeld and Williams (1972) and Kauffeld *et al*. (1975) reported that honey bee pollination increased the average weight and quality of cucumbers both in open and plots caged with honey bees. The yield of muskmelon fruits was higher in plants pollinated by bees and plants in which bees were excluded set practically no fruits. Joseph (2005) and Behera *et al*. (2010) on the genus *Memordica* suggested that for a commercial fruit and seed production, pollination management for this crop is essential and the use of hand pollination or the introduction of honey bee colonies in enclosures in India is recommended. Nidagundi (2004) reported that significantly highest length of fruits in bittergourd 26.10cm as against 13.93 and 13.60cm fruit length in open pollinated and caged plot without bees, respectively, led to pulp ratio of 0.132 as against 0.09 and 0.07 in open pollinated and caged plot without bees, respectively, highest fruit weight 129.20 as against 72.09 and 62.44 in open pollinated and caged plot without bees, respectively and yield of 118.87 q as against 68.63 and 45.23 q in open pollinated and caged plots without bees, respectively. Rao and Suryanarayana (1988) reported that there was no fruit set in watermelon plots excluded from insect pollinators. The fruit number and weight were more in honey bee pollinated crop than open pollination. Kauffeld and Nelson (1982) reported that the yield of pickling cucumber was highest in the plots caged with *A. mellifera* than open plots and was lowest in control plots. Alam and Quadir (1986) reported that plots pollinated with *A. cerana* had 15 per cent fruit set and that of hand pollinated plots had 8 per cent and isolated plots had only 3 to 5 percent fruit set in bottle gourd. Cervancia and Bergonia (1990) reported that the fruit set of cucumber in bee and open pollinated plants were 75 and 58 per cent, respectively and these were significantly higher than the non-pollinated plants (33%). Bee and open pollination also yielded heavier and uniform fruits.

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