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Foraging and Pollen Load Carrying Efficiency of Honey Bee Species on Dragon Fruit (*Hylocereus* spp. : Fam. Cactaceae)

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ABSTRACT

The flower of *Hylocereus polyrhizus* (1.98 ± 0.17 g) offered maximum yield of pollen to *Apis* species of honey bees as compared to 1.95 ± 0.26 g pollen in the flower of *H. undatus. Apis dorsata* carried maximum amount of pollen (16.50 and 16.35 mg/bee), followed by *A. mellifera* (5.80 and 5.90 mg/bee), *A. cerana* (4.60 and 4.56 mg/bee) and lowest (3.20 and 3.34 mg/bee) was recorded in case of *A. florea* from the flowers of *Hylocereus undatus* and *Hylocereus polyrhizus* respectively. Irrespective of the flowering phases of dragon fruit, the mean number of flowers visited by *Apis* species of honey bees from landing on flower upto the departure of individual bee indicated that the native Indian honey bee, *Apis cerana* ranked first in the number of flowers visited, followed by *A. dorsata, A. mellifera* and *A. florea.*

Keywords : Pollen production, Pollen carrying capacity, Foraging efficiency

DRAGON fruit, *Hylocerus* spp. is an exotic fruit crop belonging to the family Cactaceae, native to Central and South American rainforests. It has been well established as a new crop in various tropical countries due to its precocious yielding ability and its acceptability in the market. Dragon fruit has been introduced to India during late 1990s. In India, it is cultivated in Karnataka, Kerala, Tamil Nadu, Maharashtra, Gujarat, Orissa, West Bengal, Andhra Pradesh and Andaman and Nicobar Islands in a small area of less than 400 ha (Karunakaran *et al.,* 2019).

Currently, it is being cultivated in 22 countries of the tropics including Australia, Cambodia, China, Colombia, Ecuador, Guatemala, Hawaii, Indonesia, Israel, Japan, Laos, Malaysia, Mexico, New Zealand, Nicaragua, Peru, Philippines, Spain, Sri Lanka, Taiwan, Thailand, South Western USA and Vietnam. Historical evidence indicates that the French introduced the crop to Vietnam about 100 years ago and it was grown for the King. Later, it became popular among the wealthy families of the entire country. Vietnam has favourable climatic conditions for growing tropical fruits, mainly in the southern parts of Mekong Delta and in the southeast areas.

Pushpakumara *et al.,* (2005) carried out detailed investigation of pollination vectors of dragon fruit (*Hylocereus undatus* and *H. polyrhizus*), in Bulathsinhala, Sri Lanka. The most likely pollinators of dragon fruit are *Apis cerana* F. (honeybee), *Apis florea* F. (dwarf honeybee) and *Apis dorsata* F. (giant honeybee) in Bulathsinhala, Sri Lanka.

The pollination requirements and the behavior of floral visitors in two species of pitaya, *Hylocereus undatus* and *H. polyrhizus*in Northeastern Brazil witnessed the visitations of sphinx moths, ants, wasps and bees, with *Apis mellifera* accounted 86.1 per cent visits to flowers. The *H. undatus* species is independent of biotic pollination to set and produce large and well-shaped fruits, but *H. polyrhizus* shows limited self-pollination and requires biotic pollination to set fruits and also to produce larger fruits (Muniz *et al.,* 2019).

The pollination biology studies of *Oreocereus celsianus* (Salm-Dyck) A. Berger ex Riccob, a columnar cactus with restricted distribution in the subtropical Andes had showed that the flowers were frequently visited by *Patagona gigas* Vieillot, Giant Humming bird. Whereas the bees, wasps and moths were occasional visitors of the flowers. The results suggest that the Andean columnar cactus is partially specialized to pollination service performed by humming birds (Larrea and Lopez 2011).

The studies pertain to pollen production per flower of dragon fruit species, pollen load carried in corbicula and foraging efficiency of honey bee species on two types of dragon fruit was very much limited in India hence the results of this study provide the basis for future studies in India or abroad.

Material and Methods

The study of pollen production per flower of *Hylocereus undatus* (white flesh) and *H. polyrhizus* (pink flesh), the amount of pollen carried in their corbicula by different honey bees and their foraging efficiency in terms of number of flowers visited from their arrival on to the flower upto the departure was carried out during the flowering period of 2021-22 in the farmer's field at Suradenupura, Yelahanka (Tq.), Bengaluru Urban.

Pollen Output Per Flower

The sepals and petals of fully matured five floral buds of both the varieties were removed before anther dehiscence (14:00 hrs). The floral buds were covered with plastic covers. At the time of complete closing of the flower (12:00 hrs), flowers were shaken for the collection of the pollen in the plastic covers. The study was conducted both in the field as well as in the laboratory. The weight difference between the cover with pollen and the empty cover was treated as pollen yield per flower. It was expressed in grams per flower.

Pollen Load Carrying Capacity of Honey Bees

The returning forager bees of *A. cerana* and *A. mellifera* with pollen load in their corbicula were captured manually at the hive entrance of their colony placed in the dragon fruit orchard. Similarly, the pollen forager of *Apis dorsata* and *Apis florea* with fully packed pollen in their corbicula while foraging on flowers of dragon fruit were captured manually by using glass vials and pollen loads were removed and weighed. The pollen collected by 10 bees belonged to respective honey bee species were removed by using forceps and weighed. The mean weight of pollen carried by bees was expressed in mg per bee.

Foraging Efficiency of *Apis* Species of Honey Bees

The four unloaded fresh bees each from *Apis dorsata* Fab., *Apis cerana* Fab., *Apis mellifera* L. and *Apis florea* Fab. were tracked from their arrival on to the flower upto departure from the flowers of *Hylocereus undatus* and *H. polyrhizus* at different time intervals during their foraging period (0600-1200 hrs) and the foraging efficiency of each species of bees was assessed in terms of number of flowers visited per four bees (Sajjanar & Eswarappa, 2015 and Shreya *et al.,* 2024).

Results and Discussion

The amount of pollen produced by flowers of *Hylocereus undatus* (white flesh) and *H. polyrhizus* (pink flesh), pollen carrying capacity of honey bees and their foraging efficiency is discussed here under.

Pollen Output

The field and laboratory estimation of pollen output per flower (Table 1) revealed that the *Hylocereus polyrhizus* (1980 ± 170 mg/flower) yielded good amount of pollen as compared to *Hylocereus undatus* (1950±260 mg/flower). Although the difference is marginal, both species demonstrated a high pollen yield, which is advantageous for entomophilous pollination. This high output could be attributed to the large floral structures and abundant stamens commonly observed in cactaceous species, which are adapted to attract nocturnal and crepuscular pollinators.

Pollen Carrying Capacity

The pollen load weight varied significantly among *Apis* species from the flowers of two types of dragon

Table 1

Pollen output (mg/flower) and pollen carrying capacity of *Apis* species (mg/bee) from the flowers of *Hylocereus undatus* and *Hylocereus polyrhizus*

Apis species	*Hylocereus undatus* (white flesh)			*Hylocereus polyrhizus* (pink flesh)		
	Pollen yield (mg/ flower)	Pollen load (mg/ bee)	Estimated maximum No. of bees accommodated /flower	Pollen yield (mg/ flower)	Pollen load (mg/ bee)	Estimated maximum No. of bees accommodated /flower
A. dorsata		16.50 [a]	118.18		16.35 [a]	121.10
A. cerana	1950 ± 260	4.60 [c]	423.91	1980 ± 170	4.56 [c]	434.21
A. mellifera		5.80 [b]	336.20		5.90 [b]	335.59
A. florea		3.20 [d]	609.37		3.34 [d]	592.81
Mean	-	7.52	-	-	7.53	-
S.Em ±±	-	0.13	-	-	0.25	-
CD@5%	-	0.40	-	-	0.80	-
CV	-	3.89	-	-	7.64	-

fruit. Among *Apis* species, the maximum pollen load weight was recorded in *A. dorsata* (16.50 and 16.35 mg/bee), followed by *A. mellifera* (5.80 and 5.90 mg/ bee), *A. cerana* (4.60 and 4.56 mg/bee) and lowest (3.20 and 3.34 mg/bee) was recorded in case of *A. florea* from the flowers of *Hylocereus undatus* and *Hylocereus polyrhizus* respectively (Table 1).

The pollen output of *Hylocereus undatus* and pollen carrying capacity of *Apis* species revealed that the pollen produced by single flower accommodated maximum number of *A. florea* (609.37 bees/flower), followed by *A. cerana* (423.91 bees/flower), *A. mellifera* (336.20 bees/flower) and lowest number was in case of *A. dorsata* (118.18 bees/flower), if the individual forager from *Apis* species was allowed to forage on single flower of *H. undatus*. However, the pollen produced by a single flower of *H. polyrhizus* accommodated maximum number of *A. florea* (592.81 bees/flower), followed by *A. cerana* (434.21 bees/flower), *A. mellifera* (335.59 bees/ flower) and lowest number was in case of *A. dorsata* (121.10 bees/flower), if the individual forager from *Apis* species was allowed to forage on single flower of *Hylocereus polyrhizus* (Table 1).

Statistical analysis confirmed significant variation in pollen load among species, indicating species-specific foraging efficiency. These findings are consistent with previous studies which reported *A. dorsata* as an effective pollinator due to its foraging range, strength, and high pollen carrying capacity (Kaur *et al.,* 2016).

Foraging Efficiency of *Apis* Species of Honey Bees during Different Phases of Flowering

There are seven phases of flowering in *Hylocereus undatus* per year, started in the 1st week of May and ended in 2nd week of September. There were eight phases of flowering per year in *Hylocereus polyrhizus,* started in the 1st week of May ended in 3rd week of October. The foraging efficiency of *Apis* species honey bees was documented in all the phases of flowering.

First Phase of Flowering

The tracking of four unloaded fresh *Apis* species of honey bees from their arrival upto departure from the flowers of *Hylocereus undatus,* at different time intervals during their foraging period (0600-1200 hrs) revealed that the number of flowers visited by *Apis dorsata, A. cerana and A. mellifera* was lowest (12, 11 and 11 flowers/4bees) during 0600-0700 hrs

TABLE 2

Foraging efficiency of *Apis* species of honey bees (No. of flowers/4bees) on dragon fruit types, *Hylocereus undatus* (white flesh) and *Hylocereus polyrhizus* (pink flesh) during 1[at] phase of flowering

Apis species Time (hrs)	*Hylocereus undatus*				*Hylocereus polyrhizus*			
	A. d	*A.c*	*A.m*	*A.f*	*A.d*	*A.c*	*Am*	*A.f*
0600-0700	12.00	11.00	11.00	-	12.00	10.00	11.00	-
0700-0800	13.00	13.00	14.00	-	13.00	12.00	12.00	-
0800-0900	14.00	14.00	13.00	10.00	14.00	15.00	15.00	10.00
0900-1000	15.00	14.00	14.00	12.00	13.00	14.00	14.00	11.00
1000-1100	13.00	13.00	14.00	13.00	13.00	13.00	12.00	13.00
1100-1200	16.00	15.00	15.00	9.00	-	11.00	12.00	9.00
Mean±SD	13.83 ± 1.47	13.33 ± 1.63	13.5 ± 1.38	11.00 ±1.83	13.00 ± 0.71	12.50 ± 1.87	12.66 ± 1.63	10.75 ± 1.71
Flowers visited/ bee	3.45	3.33	3.37	2.75	3.25	3.12	3.16	2.68

Note : *A. d: Apis dorsata; A.c: Apis cerana; A.m: Apis mellifera; A.f: Apis florea*

and highest (16, 15 and 15 flowers/4bees) was recorded during 1100-1200 hrs. However, number of flowers visited by *Apis florea* was least (9 flowers/ 4bees) during 1100-1200 hrs and maximum during 1000-1100 hrs (13 flowers/4bees). The number of flowers visited by individual forager was maximum in case of *Apis dorsata* (3.45 flowers/bee), followed by *A. mellifera* (3.37 flowers/bee), *A. cerana* (3.33 flowers/bee) and the lowest (2.75 flowers/bee) was recorded in case of *A. florea* (Table 2). Similarly, the number of flowers visited on *Hylocereus polyrhizus* by *Apis dorsata, A. cerana and A. mellifera* was lowest (12, 10 and 11 flowers/4bees) during 0600-0700 hrs and highest (14, 15 and 15 flowers/4 bees) was recorded during 08:00-09:00 hrs. However, the number of flowers visited by *A. florea* was least (9 flowers/4 bees) during 11:00-12:00 hrs and maximum (13 flowers/4 bees) during 10:00-11:00 hrs. The number of flowers visited by individual forager of *A. dorsata* was highest (3.25 flowers/bee) followed by *A. mellifera* (3.16flowers/bee), *A. cerana* (3.12 flowers/bee) and lowest (2.68 flowers/bee) was recorded in *A. florea* (Table 2).

During H. undatus flowering, *A. dorsata, A. cerana*, and *A. mellifera* exhibited their lowest visitation rates between 0600-0700 hrs (12, 11 and 11 flowers per 4 bees respectively), with visits peaking between 1100-1200 hrs (16, 15, and 15 flowers per 4 bees) suggesting a gradual increase in activity as the morning progresses. Conversely, *A. florea* displayed a contrasting pattern, with its lowest visits (9 flowers per 4 bees) during 1100-1200 hrs and the highest at 1000-1100 hrs (13 flowers per 4 bees). Similar patterns were observed on *H. polyrhizus*: the first three species showed maximum foraging early in the morning (0800-0900 hrs), while *A. florea* again peaked during 1000-1100 hrs and was least active between 1100-1200 hrs.

Such shifts align with findings in other studies where *A. florea* foraging activity peaked later in the morning (around 1100 hrs), with minimal activity at dawn (0600 hrs). For instance, Gayen & Ghorai (2023) observed that *A. florea* had peak foraging at 1100 hrs and minimal activity at 0600 hrs, particularly on wax apple, Syzygium samarangense.

Second Phase of Flowering

The number of flowers visited by *Apis dorsata, A. cerana and A. mellifera* was highest (15 flowers/4 bees) during 0900-1000 hrs and lowest (9, 10 and 11 flowers/4bees) during 1100-1200 hrs, whereas the number of flowers visited by *A. florea* was maximum during 1000-1100 hrs (13 flowers/4 bees) and least (10 flowers/4 bees) was recorded during 1100-1200

TABLE 3

Foraging efficiency of *Apis* species of honey bees (No. of flowers/ 4 bees) on dragon fruit types, *Hylocereus undatus* (white flesh) and *Hylocereus polyrhizus* (pink flesh)during 2nd phase of flowering

Apis species Time (hrs)	*Hylocereus undatus*				*Hylocereus polyrhizus*			
	A. d	*A.c*	*A.m*	*A.f*	*A.d*	*A.c*	*Am*	*A.f*
0600-0700	13.00	12.00	12.00	-	13.00	11.00	12.00	-
0700-0800	13.00	13.00	13.00	-	14.00	12.00	12.00	-
0800-0900	14.00	13.00	14.00	11.00	15.00	16.00	15.00	11.00
0900-1000	15.00	15.00	15.00	12.00	13.00	14.00	14.00	12.00
1000-1100	13.00	13.00	13.00	13.00	12.00	12.00	13.00	13.00
1100-1200	9.00	10.00	11.00	10.00	-	10.00	11.00	10.00
Mean±SD	12.66 ± 1.86	12.66 ± 1.50	13.00 ± 1.41	11.00 ±1.41	13.40 ± 0.54	12.50 ± 2.16	12.83 ± 1.47	11.50 ± 1.30
Flowers visited/ bee	3.16	3.16	3.25	2.75	3.35	3.12	3.20	2.80

Note : *A. d: Apis dorsata; A.c: Apis cerana; A.m: Apis mellifera; A.f: Apis florea*

TABLE 4

Foraging efficiency of *Apis* species of honey bees (No. of flowers/4 bees) on dragon fruit types, *Hylocereus undatus* (white flesh) and *Hylocereus polyrhizus* (pink flesh) during 3rd phase of flowering

Apis species Time (hrs)	*Hylocereus undatus*				*Hylocereus polyrhizus*			
	A. d	*A.c*	*A.m*	*A.f*	*A.d*	*A.c*	*Am*	*A.f*
0600-0700	12.00	12.00	12.00	-	13.00	11.00	11.00	-
0700-0800	13.00	13.00	14.00	-	14.00	15.00	15.00	-
0800-0900	15.00	15.00	16.00	11.00	15.00	16.00	16.00	12.00
0900-1000	14.00	13.00	14.00	12.00	14.00	14.00	14.00	12.00
1000-1100	13.00	14.00	14.00	14.00	14.00	13.00	14.00	14.00
1100-1200	10.00	11.00	11.00	8.00	-	13.00	12.00	10.00
Mean±SD	12.83 ± 12.13	12.83 ± 1.60	13.50 ± 1.64	11.25 ±2.06	14.00 ± 0.70	13.67 ± 1.63	13.67 ± 1.75	12.00 ± 1.63
Flowers visited/ bee	3.20	3.20	3.37	2.81	3.50	3.41	3.41	3

Note : *A. d: Apis dorsata; A.c: Apis cerana; A.m: Apis mellifera; A.f: Apis florea*

hrs. The number of flowers visited by individual foragers of *Apis dorsata* and *A. cerana* was highest (3.16 flowers/bee), followed by that of *A. mellifera* (3.25 flowers/bee) and lowest (2.75 flowers/bee) was recorded in *A. florea* on *Hylocereus undatus* flowers (Table 3).

On Hylocereus undatus, Apis dorsata, A. cerana, and A. mellifera reached their highest flower visitation rates (15 flowers per 4 bees) between 0900-1000 hrs, with visits declining to 9, 10, and 11 flowers respectively during 1100-1200 hrs. In contrast, A. florea peaked later, visiting 13 flowers per 4 bees during 1000-1100 hrs and dropping to just 10 during 1100-1200 hrs. These temporal distinctions likely reflect differences in thermal or light preferences influencing foraging onset and duration, echoing similar behavior patterns reported in cucurbit crops by Pateel and Sattagi (2007) in Karnataka, where A.

dorsata and *A. cerana* both exhibit peak foraging late in the morning with highest rates around 10:30-11:30 hrs before tapering off towards early afternoon.

The number of flowers visited by *Apis dorsata, A. cerana* and *A. mellifera* on *Hylocereus polyrhizus* was highest (15, 16 and 15 flowers/4bees) during 0800-0900 hrs, whereas lowest number of flowers were visited by *Apis dorsata* (12 flowers/4bees) during 1000-1100 hrs, *A. cerana* (10 flowers/4bees) and *A. mellifera* (11 flowers/4bees) during 1100-1200 hrs, respectively. *A. florea* visited maximum number of flowers (13 flowers/4bees) during 1000-1100 hrs and minimum (10 flowers/4bees) during 1100-1200 hrs. The number of flowers visited by individual forager of *Apis dorsata* (3.35 flowers/bee) was highest, followed by *A. mellifera* (3.20 flowers/bee), *A. cerana* (3.12 flowers/bee) and lowest (2.80 flowers/bee) was recorded in case of *A. florea* (Table 3).

Third Phase of Flowering

Apis dorsata, A. cerana and A. mellifera visited lowest number of flowers (10, 11 and 11 flowers/4bees) during 1100-1200 hrs and the highest (15, 15 and 16 flowers/4bees) was recorded during 0800-0900 hrs. However, number of flowers visited by *A. florea* was least (8 flowers/4bees) during 1100-1200 hrs and maximum during 1000-1100 hrs (14 flowers/4bees). The number of flowers visited by individual foragers of *A. dorsata* and *A. cerana* was highest (3.20 flowers/bee) followed by *A. mellifera* (3.37 flowers/bee) and lowest (2.81 flowers/bee) was recorded in case of *A. florea* on *H. undatus* flowers (Table 4).

The number of flowers visited by *Apis dorsata, A. cerana and A. mellifera* on *Hylocereus polyrhizus* was lowest (13, 11 and 11 flowers/4bees) during 0600-0700 hrs and highest (15, 16 and 16 flowers/4bees) was recorded during 0800-0900 hrs, whereas the number of flowers visited by *A. florea* was least (10 flowers/4bees) during 1100-1200 hrs and maximum (14 flowers/4bees) during 1000-1100 hrs. The number of flowers visited by individual foragers of *Apis dorsata* was highest (3.50 flowers/bee), followed by that of *A. cerana* (3.41 flowers/bee), *A. mellifera* (3.41 flowers/bee) and lowest was recorded in case of *A. florea* (3 flowers/bee) on *H. polyrhizus* flowers (Table 4).

On H. undatus, *Apis dorsata*, *A. cerana* and *A. mellifera* showed peak flower visits 0800-0900 hrs (15, 15, and 16 flowers/4 bees respectively), with a notable decline by 1100-1200 hrs (10, 11, and 11 flowers/4 bees). *Apis florea* followed a different rhythm, peaking 1000-1100 hrs (14 flowers/4 bees)

Table 5

Foraging efficiency of *Apis* species of honey bees (No. of flowers/4bees) on dragon fruit types, *Hylocereus undatus* (white flesh) and *Hylocereus polyrhizus* (pink flesh)during 4th phase of flowering

Apis species Time (hrs)	*Hylocereus undatus*				*Hylocereus polyrhizus*			
	A. d	*A.c*	*A.m*	*A.f*	*A.d*	*A.c*	*Am*	*A.f*
0600-0700	12.00	12.00	12.00	-	13.00	13.00	11.00	-
0700-0800	13.00	14.00	14.00	-	15.00	16.00	14.00	-
0800-0900	17.00	16.00	16.00	13.00	16.00	18.00	16.00	13.00
0900-1000	14.00	14.00	14.00	13.00	13.00	15.00	13.00	14.00
1000-1100	14.00	14.00	13.00	15.00	12.00	13.00	11.00	15.00
1100-1200	10.00	11.00	11.00	10.00	-	12.00	10.00	12.00
Mean±SD	13.33 ± 2.33	13.50 ± 1.76	13.33 ± 1.75	12.75 ± 2.06	13.80 ± 1.64	14.50 ± 2.25	12.50 ± 2.25	13.50 ± 1.91
Flowers visited/ bee	3.33	3.37	3.33	3.18	3.45	3.62	3.12	3.37

Note : *A. d: Apisdorsata; A.c: Apiscerana; A.m: Apismellifera; A.f: Apis florea*

TABLE 6

Foraging efficiency of *Apis* species of honey bees (No. of flowers/4bees) on dragon fruit types, *Hylocereus undatus* (white flesh) and *Hylocereus polyrhizus* (pink flesh), during 5th phase of flowering

Apis species Time (hrs)	*Hylocereus undatus*				*Hylocereus polyrhizus*			
	A. d	*A.c*	*A.m*	*A.f*	*A.d*	*A.c*	*Am*	*A.f*
0600-0700	11.00	13.00	12.00	-	11.00	11.00	10.00	-
0700-0800	14.00	15.00	14.00	-	14.00	15.00	15.00	-
0800-0900	16.00	16.00	16.00	14.00	15.00	17.00	17.00	12.00
0900-1000	13.00	14.00	15.00	14.00	14.00	15.00	15.00	16.00
1000-1100	15.00	14.00	14.00	15.00	13.00	13.00	14.00	15.00
1100-1200	10.00	11.00	10.00	10.00	-	13.00	12.00	10.00
Mean±SD	13.17 ± 2.22	13.83 ± 1.72	13.50 ± 2.16	13.25 ± 2.21	13.40 ± 1.51	14.00 ± 2.00	13.83 ± 2.40	13.25 ± 2.75
Flowers visited/ bee	3.29	3.45	3.37	3.31	3.35	3.50	3.45	3.31

Note : *A. d: Apis dorsata; A.c: Apis cerana; A.m: Apis mellifera; A.f: Apis florea*

and reaching its lowest point 1100-1200 hrs (8 flowers/4 bees). Similar patterns emerged on H. polyrhizus, with early morning peaks for the first three species and mid-morning dominance by A. florea. This staggered activity aligns with findings from other studies conducted by Sharma *et al.* (2001), in mustard, garlic, carrot and sun flower. Researchers observed that Apis florea spent maximum time per flower and visited least number of flowers/umbels per minute. In contrast, A. dorsata and A. mellifera were more efficient, visiting more flowers per minute per head. This suggests temporal partitioning among Apis species, reducing direct competition and ensuring extended pollination coverage throughout the morning.

TABLE 7

Foraging efficiency of *Apis* species of honey bees (No. of flowers/4bees)on dragon fruit types, *Hylocereus undatus* (white flesh) and *Hylocereus polyrhizus* (pink flesh), during 6th phase of flowering

Apis species Time (hrs)	*Hylocereus undatus*				*Hylocereus polyrhizus*			
	A. d	*A.c*	*A.m*	*A.f*	*A.d*	*A.c*	*Am*	*A.f*
0600-0700	12.00	14.00	12.00	-	10.00	11.00	11.00	-
0700-0800	14.00	15.00	14.00	-	13.00	15.00	13.00	-
0800-0900	16.00	16.00	18.00	12.00	14.00	15.00	14.00	10.00
0900-1000	14.00	15.00	15.00	15.00	15.00	16.00	15.00	14.00
1000-1100	14.00	14.00	13.00	16.00	13.00	14.00	13.00	15.00
1100-1200	10.00	11.00	10.00	10.00	-	13.00	12.00	12.00
Mean±SD	13.33 ± 1.96	14.17 ± 1.72	13.67 ± 2.73	13.25 ± 2.62	13.00 ± 1.87	14.00 ± 1.54	13.00 ± 1.67	12.75 ± 2.21
Flowers visited/ bee	3.33	3.54	3.41	3.31	3.25	3.50	3.25	3.18

Note : *A. d: Apis dorsata; A.c: Apis cerana; A.m: Apis mellifera; A.f: Apis florea*

Fourth Phase of Flowering

The number of flowers visited by *Apis dorsata, A. cerana and A. mellifera* was highest (17, 16 and 16 flowers/4bees) recorded during 0800-0900 hrs and the lowest (10, 11 and 11 flowers/4bees) was during 1100-1200 hrs. However, number of flowers visited by *Apis florea* was maximum (15 flowers/4 bees) during 1000-1100 hrs and minimum (10 flowers/ 4bees) was during 1100-1200 hrs. The number of flowers visited by individual forager of *A. cerana* was highest (3.37 flowers/bee), followed by *A. dorsata* (3.33 flowers/bee), *A. mellifera* (3.33 flowers/bee) and the lowest (3.18 flowers/bee) was recorded in case of *A. florea* on *Hylocereus undatus* flowers (Table 5).

The number of flowers visited by *Apis dorsata, A. cerana and A. mellifera* on *Hylocereus polyrhizus* was highest (16, 18 and 16 flowers/4bees) which was recorded during 0800-0900 hrs, whereas lowest number of flowers in case of *A. dorsata* (12 flowers/4bees) during 1000-1100 hrs, in *A. cerana* (12 flowers/4bees) and *A. mellifera* (10 flowers/4bees) during 1100-1200 hrs, respectively. *Apis florea* visited maximum number of flowers (15 flowers/4bees) during 1000-1100 hrs and minimum (12 flowers/ 4 bees) during 1100-1200 hrs. The number of flowers visited by individual forager of A. cerana was highest (3.62 flowers/bee), followed by that of *A. dorsata* (3.45flowers/bee), *A. florea* (3.37flowers/bee) and lowest (3.12 flowers/bee) was recorded in case of *A. mellifera* (Table 5).

Fifth Phase of Flowering

The number of flowers visited by *Apis dorsata, A. cerana and A. mellifera* was lowest (10, 11 and 11 flowers/4bees, respectively) during 1100-1200 hrs and highest (16 flowers/4bees) was recorded during 0800-0900 hrs. However, the number of flowers visited by *A. florea* was least (10 flowers/4 bees) during 1100-1200 hrs and maximum during 1000-1100 hrs (15 flowers/4bees). The number of flowers visited by individual forager of *A. cerana* was highest (3.45 flowers/bee), followed by *A. mellifera* (3.37 flowers/bee), *A. florea* (3.31 flowers/bee) and lowest (3.29 flowers/bee) was recorded in case of *A. dorsata* on *Hylocereus undatus* flowers (Table 6).

The number of flowers visited by *A. dorsata, A. cerana and A. mellifera* on *Hylocereus polyrhizus* was lowest (11, 11 and 10 flowers/4bees) during 0600-0700 hrs and highest (15, 17 and 17 flowers/ 4 bees) during 0800-0900 hrs. However, the number of flowers visited by *A. florea* was least (10 flowers/ 4bees) during 1100-1200 hrs and maximum (16 flowers/4 bees) during 0900-1000 hrs. The number

TABLE 8

Foraging efficiency of *Apis* species of honey bees (No. of flowers/4bees) on dragon fruit types, *Hylocereus undatus* (white flesh) and *Hylocereus polyrhizus* (pink flesh), during 7th phase of flowering

Apis species Time (hrs)	*Hylocereus undatus*				*Hylocereus polyrhizus*			
	A. d	*A.c*	*A.m*	*A.f*	*A.d*	*A.c*	*Am*	*A.f*
0600-0700	13.00	12.00	12.00	-	10.00	12.00	11.00	-
0700-0800	15.00	14.00	13.00	-	13.00	16.00	15.00	-
0800-0900	17.00	16.00	16.00	11.00	15.00	17.00	16.00	13.00
0900-1000	13.00	15.00	15.00	13.00	14.00	16.00	14.00	13.00
1000-1100	14.00	13.00	13.00	16.00	13.00	14.00	14.00	16.00
1100-1200	10.00	11.00	11.00	13.00	-	13.00	13.00	10.00
Mean±SD	13.67 ± 1.96	13.50 ± 1.37	13.33 ± 1.86	13.25 ± 2.06	13.40 ± 2.60	14.67 ± 1.96	13.83 ± 1.72	13.00 ± 2
Flowers visited/ bee	3.41	3.37	3.33	3.31	3.35	3.66	3.45	3.25

Note : *A. d: Apis dorsata; A.c: Apis cerana; A.m: Apis mellifera; A.f: Apis florea*

TABLE 9

Foraging efficiency of Apis species of honey bees (No. of flowers/4 bees) on dragon fruit type Hylocereus polyrhizus (pink flesh), during 8th phase of flowering

Apis species / Time (hrs)	*Hylocereus polyrhizus*			
	A. d	*A.c*	*A.m*	*A.f*
0600-0700	12.00	10.00	11.00	-
0700-0800	15.00	13.00	15.00	-
0800-0900	17.00	15.00	16.00	11.00
0900-1000	16.00	14.00	13.00	14.00
1000-1100	13.00	13.00	12.00	17.00
1100-1200	-	11.00	12.00	13.00
Mean±SD	14.60±2.30	12.67±1.86	13.17±2.04	13.75±2.5
Flowers visited/ bee	3.65	3.16	3.29	3.43

Note : *A. d: Apis dorsata; A.c: Apis cerana; A.m: Apis mellifera; A.f: Apis florea*

of flowers visited by individual forager of *A. cerana* was highest (3.50 flowers/bee) followed by that of *A. mellifera* (3.45flowers/bee), *A. dorsata* (3.35 flowers/bee) and lowest (3.31 flowers/bee) was recorded in case of *A. florea* (Table 6).

Sixth Phase of Flowering

The number of flowers visited by *Apis dorsata, A. cerana and A. mellifera* was highest (16, 16 and 18 flowers/4bees, respectively) during 0800-0900 hrs and lowest (10, 11 and 10 flowers/4 bees) was recorded during 1100-1200 hrs. However, the number of flowers visited by *A. florea* was maximum (16 flowers/4 bees) during 1000-1100 hrs and minimum (10 flowers/4 bees) during 1100-1200 hrs. The number of flowers visited by individual forager of *A. cerana* was highest (3.54 flowers/bee), followed by *A. mellifera* (3.41 flowers/bee), *A. dorsata* (3.33 flowers/bee) and lowest (3.31 flowers/bee) was recorded in *A. florea* on *Hylocereus undatus* flowers (Table 7).

The number of flowers visited by *Apis dorsata, A. cerana and A. mellifera* on *Hylocereus polyrhizus* was highest (15, 16 and 15 flowers/4 bees, respectively) during 0900-1000 hrs and lowest (10, 11 and 11 flowers/4bees, respectively) during 0600-0700 hrs. However, the number of flowers visited by *A. florea* was maximum (15 flowers/4bees) during 1000-1100 hrs and minimum (10 flowers/4bees) during 0800-0900 hrs. The number of flowers visited by individual foragers of *A. cerana* was highest (3.50 flowers/bee), followed by same number of flowers visited by *A. mellifera* (3.25 flowers/bee), *A. dorsata*. (3.25 flowers/bee) and the lowest (3.18 flowers/bee) was recorded in case of *A. florea* (Table 7).

Seventh Phase of Flowering

The number of flowers visited by *Apis dorsata, A. cerana and A. mellifera* was lowest (10, 11 and 11 flowers/4bees, respectively) during 1100-1200 hrs and highest (17, 16 and 16 flowers/4bees, respectively) during 0800-0900 hrs. However, the number of flowers visited by *A. florea* was least (11 flowers/4bees) during 0800-0900 hrs and maximum (16 flowers/4bees) during 1000-1100 hrs. The number of flowers visited by individual forager of *A. dorsata* was highest (3.41 flowers/bee), followed by *A. cerana* (3.37 flowers/bee), *A. mellifera* (3.33 flowers/bee) and lowest (3.31 flowers/bee) was recorded in case of *A. florea* on *Hylocereus undatus* flowers (Table 8).

The number of flowers visited by A. dorsata, *A. cerana* and *A. mellifera* on Hylocereus polyrhizus was lowest (10, 12 and 11 flowers/4 bees, respectively) during 0600-0700 hrs and highest (15, 17 and 16 flowers/4 bees, respectively) during 0800-0900 hrs. However, the number of flowers visited by *Apis florea* was least (10 flowers/4bees) during 1100-1200 hrs and maximum (16 flowers/4bees) during 1000-1100 hrs. The number of flowers visited by individual forager of *A. cerana* was highest (3.66 flowers/bee), followed by *A. mellifera* (3.45 flowers/bee), *A . dorsata* (3.35flowers/bee) and lowest (3.25 flowers/bee) was recorded in case of *A. florea* (Table 8).

Eighth Phase of Flowering

The tracking of four unloaded fresh *Apis* species of honey bees from their arrival upto departure from the flowers of *Hylocereus polyrhizus,* at different time intervals during their foraging period revealed that the number of flowers visited by *Apis dorsata, A. cerana* and *A. mellifera* was lowest (12, 10 and 11 flowers/4 bees, respectively) during 0600-0700 hrs and highest (17, 15 and 16 flowers/4bees, respectively) was recorded during 0800-0900 hrs. However, the number of flowers visited by *A. florea* was least (11 flowers/4 bees) during 0800-0900 hrs and maximum (17 flowers/4 bees) during 1000-1100 hrs. The number of flowers visited by individual forager of *A. dorsata* was highest (3.65 flowers/bee) followed by *A. florea* (3.43 flowers/bee), *A. mellifera* (3.29 flowers/bee) and lowest (3.16 flowers/bee) was recorded in case of *A. cerana* (Table 9).

Changes across the eight flowering phases were minimal, peak visitation remained mid-morning (0800-1000 hrs), while late morning (1100-1200 hrs) consistently showed reduced activity likely due to closing of flower, rising of heat and declining nectar/pollen rewards.

The statistical analysis shows that early to mid-morning (0800-1000 hrs) is the most effective window across phases and species. The honey bee species *A. dorsata* excels in efficiency whereas, *A. florea* compensates with higher visitation frequency. Flowering windows and bee activity should guide management strategies for optimal pollination.

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REFERENCES

LARREA-ALCAZAR, D. M. AND LOPEZ, R. P., 2011, Pollination biology of *Oreocereus celsianus* (Cactaceae), a columnar cactus inhabiting the high subtropical Andes. *Plant Systematics and Evolution*, **295** (1) :129 - 137.

KARUNAKARAN, G., ARIVALAGAN, M. AND SRIRAM, S., 2019, Dragon fruit country report from India. Dragon fruit Network: Marketing and the whole value chain and steering committee meeting report.

MUNIZ, J. P. D. O., BOMFIM, I. G. A., CORREA, M. C. D. M. AND FREITAS, B. M., 2019, Floral biology, pollination requirements and behavior of floral visitors in two species of pitaya1. *Revista Ciencia Agronomica*, **50** : 640 - 649.

PUSHPAKUMARA, D. K. N. G., GUNASENA, H. P. M. AND KARYAWASAM, M., 2005, Flowering and fruiting phenology, pollination vectors and breeding system of dragon fruit (*Hylocereus* spp.). *Sri Lankan J. Agric. Sci.,* **42** : 81 - 91.

SAJJANAR, S. M. AND ESWARAPPA, G. 2015, Bee pollination in crop production of sesame (*Sesamum indicum* L.). *Mysore J. Agri. Sci.,* **49** (4) : 703 - 707.

SHREYA R. PATIL, G. ESWARAPPA, AMALA UDAYAKUMAR AND JAGADISH, K. S., 2024, Floral biology and floral behavior of dominant flower visitors of lucerne *Medicago sativa* L.). *Mysore J. Agric. Sci.,* **58** (2) : 296 - 303.