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Pollination Potential of (*Apis cerana indica*) in Pumpkin (*Cucurbita moschata* Duchex Poir*)*

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ABSTRACT: The activity of *Apis cerana indica* is heavily influenced by weather and environmental conditions, factors such as temperature, humidity, rainfall, and wind can affect bee foraging behavior and the frequency of their visits to pumpkin flowers. The crop pollination of pumpkin flowers is greatly aided by honey bees. An experiment was conducted at Coimbatore, Tamil Nadu, to investigate the pollination potential and effectiveness of Indian bees (*A. cerana indica*) on pumpkin. The abundance and diversity of forage in both male and female pumpkin flowers, measured asforagers/flower/min were recorded. In three different situations *viz*., open pollination, bee pollination and pollination exclusion the pumpkin fruit set and yield were evaluated. The foraging rate of bees on the male flowers (0.81/min) was higher than on female flowers (0.49/min) and the floral handling time in seconds on male and female flowers was5.03 and 3.85 respectively. *A. cerana indica* foraging activity peaked between 7:00 - 09:00 am with 30.06 foragers / 5 minutes. *A. florea* was found to possess the highest Pollination Efficiency Index (2.49 / 5 inflorescences/ 5 min). At the hive entrance, incoming and outgoing bees was high at 7:00 - 09:00 am in the morning. *A. cerana indica* colony growth parameters *viz.*, the adult bee population, increased by 11.77% and the sealed honey area by 33.10%. Based on the results of pollination studies, it was found that managed bee-pollinated plots produced more fruits 3.3 fruits/ plant and 39.7t/ha than open pollination conditions (2.6 fruits/ plant) and (34.6t/ha). In contrast, the pollination exclusion condition failed to produce any fruit.

Keywords: *Apis cerana indica*, Pumpkin, Pollination efficiency, Foraging activity, Bees abundance, Pollination efficiency.

INTRODUCTION

Many cucurbits experience a lack of pollination, primarily due to their monoecious flowering nature. This emphasizes the importance of pollinators for successful fruit formation and the development of high-quality seeds. Honey bees are particularly vital in pollinating around 80% of crops, while also contributing to the production of approximately 1.6 million tons of honey (FAO, 2015). The use of managed bee pollination, specifically with *A. cerana indica* colonies, has shown significant improvements in yield across various agricultural and horticultural crops. For instance, it has resulted in a 79% increase in sunflower seed yield, a 55% increase in mustard seed yield, a 64% increase in safflower seed yield, and a 40% increase in coconut seed yield. According to Mohapatra *et al*. (2019), the estimated losses resulting from inadequate pollination in cross-pollinated crops in India ranged from Rs. 10,000 to Rs. 55,000 per hectare.

A variety of cucurbitaceous plants include the pumpkin, formally known as *Cucurbita moschata* Duch.ex Poir. According to archaeological data, Mexico and Peru were the main genesis countries for pumpkins, which are thought to have been widely grown in North and South America. Later, South American traders brought the pumpkin to India.

Pumpkin fruit is highly nutritious, containing significant amounts of carotene, which is a precursor of Vitamin A. The flesh of the pumpkin has a moisture content of 92.6g, a protein content of 1.4%, and a fat content of 0.1g per 100g of fresh pulp. It also contains 4.6% carbohydrates, 10mg of calcium, 30mg of phosphorus, 0.7mg of iron, 82.1 U of vitamin A, and 2mg of Vitamin C per 100g of fresh weight. In terms of energy, it provides approximately 25 calories. Pumpkins are utilized as fresh vegetables, processed foods, and as feed for livestock (Thamburaj and Narendrasingh 2000).

Honey bees act as micromanipulators, collecting pollen and nectar from flowers. As a result, they assist in the pollination process, creating a mutualistic relationship between the bees and the flowers (Hemalatha *et al*., 2018). Due to the presence of male and female flowers separately on the same plant, the flowers are not self-pollinated. (Anandhabhairavi *et al*., 2020).

The survival efficiency of bees relies on their foraging activity, which is closely tied to the size of the colony population. To assess this relationship, the researchers conducted an observation on colony maintenance by

counting the number of workers leaving and returning to the hive with pollen and nectar during a specific time frame Reddy *et al.* (2015).

Similar to other cucurbits, Pumpkins are highly appealing to honey bees due to their flowers producing abundant nectar and/or pollen. Effective bee management is crucial as it not only leads to honey and wax production but also significantly improves the production of high-quality fruits and seeds through efficient pollination.

MATERIALS AND METHODS

In 2023, a field study was carried out in Coimbatore District, Tamil Nadu to examine the foraging habits of *A. cerana indica*. To conduct the study, 5 randomly selected plants were tagged, and 2 blossoms per plant were observed every 3 days.

Managed Bee Pollinators Foraging on Pumpkin Blooms. The number of foragers per flower per minutes was used to measure pollinator abundance, and the foraging rate was measured as the amount of time each individual bee pollinator spent per flower per minute on both male and female flowers. Both measurement were made using a stopwatch at 3-days intervals during the height of pollinator activity. Peak foraging activity was observed at hourly intervals between 06:00 and 18:00 hours, with the number of foragers visiting each flower recorded for 5 minutes at 3-days intervals (Yogapriya *et al*., 2019).

Pollination Efficiency Index. To quantify loose pollen grains, we used a sweep net to gather foraging bees in the field between 07:00 a.m. and 09:00 a.m. during peak foraging hours. Subsequently, the bees were placed in a glass vial filled with 70% alcohol and forcefully agitated to flush pollen grains from their bodies. A 5ml volume of the alcohol solution was created. To evaluate a small sample (0.01ml aliquot) of the solution, we used a Neubauer Haemocytometer and a microscope. To ensure multiple replications, this procedure was performed five times. The next step involvedcomputing the total number of pollen grains in the 5 ml solution using the count from replicates (Balina *et al.*, 2012). Sihag (1988) developed procedures for determining the pollination efficiency index for each visitor species. This is generally the product of the performance score of LP (loose pollen sticking to the insect's body) and the performance score (PS) of the mean number of insect visitors (PA) during peak blooming hours.

Pollination Efficiency Index = PS of LP × PS of PA

$$\text{Where PS of LP} = \frac{\text{LPi}}{\Sigma_{i=1}^{n}\ \text{LPi}}$$

$$\text{PS of PA} = \frac{\text{LPi}}{\Sigma_{i=1}^{n}\ \text{PAi}}$$

Evaluation of pollination potential of Asiatic hive bees in pumpkin. In an experiment utilizing a Randomized Block Design (RBD), the pollination yield of pumpkin was assessed using various methods. The experiment consisted of three treatments and seven replications. Each replication included five plants, resulting in a total of 35 plants.

After the pumpkin plants began flowering, the female flower were labelled with tags to estimate the yield. Throughout the period of experiment, 70 flowers (2 female flowers per plant) were tagged.

The three treatments used in the experiment were as follows

a) Pollinator Exclusion (T1): In this procedure, sleeves were placed around the female flowers prior to their blooming. The cages were taken down a week after flowering, enabling unrestricted pollination.

b) Bee pollination(T2): For this treatment, three Indian Bee colonies with frame strength were introduced to the pumpkin field at the time of flowering initiation in 10% of the plants. The bees facilitated pollination in this treatment.

c) Open pollinated (T3): This treatment served as the control, allowing for natural open pollination to occur without any specific interventions.

By comparing the yield data obtained from these different treatments, which we aimed to assess the impact of pollinator exclusion, bee pollination, and open pollination on the yield of pumpkin plants.

The Randomized Block Design helped ensure that the experimental conditions were controlled and accounted for potential sources of viability

Parameters Regarding Yield

Fruit yield, weight, and fruit production per plant

In the study by Manchare *et al.* (2019), fruits on marked plants were counted and their weights were recorded. The researchers randomly picked 10 fruits from the tagged plants, weighed them using a weighing scale, and recorded their weights.

Subsequently, all the fruits from each tagged plant were collected, weighed, and the total yield was determined. The yield was then converted to yield per hectare, likely by accounting for the total number of plants and the area of land under cultivation.

The purpose of this study was likely to determine the fruit yield of the tagged plants and assess the productivity of the crop per unit area, providing important information for agricultural purposes and yield optimization.

***Apis cerana indica* foraging activity at the hive entrance.** For the day, Observation were made during three specific time periods07:00-09:00 h, 11:00-13:00 h, and 15:00-17:00h. Each observation period latest for 5 minutes, the number of returning foragers carrying nectar (Corbicula without pollen), pollen (Corbicula with pollen), as well as the number of outgoing foragers at the hive entrance were counted.

Colony development of *A. cerana indica* placed in pumpkin field:

Using a transparent OHP sheet grid of 1 cm^2, colony development characteristics such as sealed brood area, sealed honey area, pollen storage area, and adult bee population were measured. Observation were made at interval of 15 days, and the percentage increase in colony growth parameters was compared.

Statistical Assessment. ANOVA (Analysis of Variance) was used to analyses the data, and a significant level of P = 0.05 was used for the Least significance difference (LSD). MS Excel and the

AGRES Software were used to carry out all additional calculations.

RESULT AND DISCUSSION

The results of observations on *A. cerana indica* foraging activity indicated that male flowers had more forager bee abundance than female flowers Table 1 (Fig. 1). Male flowers showed maximum bee abundances ranging from 1.01 bees per flower per minute to a minimum of 0.59 bees per flower per minute, whereas on female flowers, the bee abundance ranged from 0.61 bees per flower per minutes to 0.34 bees per minute.

Forager spent more time on male flowers (3.08 to 5.91 s) (Table 2, Fig. 2). On the other hand, for female flowers, the range was 2.66 to 4.75s. According to the mentioned above data, the average number of bees per flower per minute for both male and female flowers was 0.65 and the average foraging time was 4.44 s. These results are in accordance with findings of Yogapriya *et al.* (2019), who observed that the abundance of *A. cerana indica* in bitter gourd flower was 0.90 bees/5min/m^2 and the average duration spent by an individual bee in each flower was 3.91 second.

Pollination efficiency index. The amount of loose pollen grains adhered to the body of *A. cerana indica* (pollen grains) was counted to determine the efficacy of pollination. Among the studied bee species, *A. dorsata* (8739) had the loosest pollen grains on its body, followed by *A. cerana indica* (7953), *A. florea* (6532), *Megachila lamia* (5321). *A. florea* had the highest pollinator abundance (1.12/5 inflorescences/5 min), followed by *A. cerana indica* (0.81), *Megachila lamia*(0.51) and *A. dorsata* (0.11). The Pollination Efficiency Index (PEI) for *A. florea, A. cerana indica, Megachila lamia* and *A. dorsata* was reported to be 2.49, 2.19, 0.93, 0.32, respectively, based on the amount of loose pollen sticking to the body and the abundance or pollinators. *A. florea* was found to possess the highest Pollination Efficiency Index when compared to the other pollinators due toits greater abundance (2.49/5 inflorescences/5 min) compared to *A. cerana indica* (2.19) and *Megachila lamia* (0.93/inflorescences/ 5 min). Balina *et al*., (2012) also observed that in bitter gourd, the maximum quantity of pollen grains in *A. dorsata* was 170000.

***A. cerana indica* foraging activity at the hive entrance.** *A. cerana indica* foraging activity was observed at the hive entrance at every day at different time interval. The result showed that the mean number of incoming nectar foragers was larger (23.46) than the mean number of incoming pollen foragers (12.83). Maximum forager activity occurred between 07:00 and 09:00 h (30.06), followed by 11:00 to 13:00 h (17.65), and minimal activity occurred between 16:00 and 18:00 h (21.33) (Table 4, Fig. 3). According to Painkra *et al.* (2021), the foraging activity of Indian bee's (*Apis cerana indica*) peaked around 9.00 a.m. (14.71 bees/5 min/plant) and decreased at 5.00 p.m. (7.14 bees/5 min/plant).

Colony development of *A. cerana indica* placed in a Pumpkin field. In a hive of A. *cerana indica* placed in a pumpkin field, colony growth parameters were periodically observed. The result showed increases in the amount of sealed honey, pollen storage space, sealed brood, and colony population. The colonies showed an increase in sealed honey area of 67.44%, pollen area of 44.68%, and sealed brood area of 33.10%. Additionally, the adult population rose, rising from 2054 to 3122 bees per hive, representing an11.77% increase (Table 5). Sowmiya *et al*. (2018) reported significant increases in various parameters when Indian bee hives were placed in a *Moringa oleifera* orchard during the experimental period. These parameters include an increase in sealed honey area from 58.4 to 81.9 cm^2, pollen storage area from 40.2 to 65.9 cm2, sealed brood area from 63.9 to 89.9 cm^2, and adult population from 2171 to 3305 bees per hive. These findings support our own results, which also recorded a significant increase in sealed honey area, sealed brood area, pollen area, and colony population in Indian bee hives kept in the pumpkin field during the research.

Effect of *A. cerana indica* on pumpkin pollination and production. Bee pollination was shown to produce the highest fruit set, which was 3.32 fruits per plant, whereas open pollination (T3) produced an average of 3.12 fruits per plant. In the bee pollination (T2) condition, the fruit weight was greater (3.50kg/fruits) compared to the open pollination condition (3.37 kg/fruits). The yield for bee pollination was 39.72 t/ha, whereas the yield for open pollination was 34.61t/ha. Under the sleeve condition in pollinator exclusion (T1), no fruit set was seen (Table 6). The results of the present findings are in accordance with the result of Dorjay *et al.* (2017) who reported maximum fruit set of 87.14% under bee pollination condition and 65.21% under open pollination condition respectively. Additionally, Deyto and Cervancia (2009) found that bitter gourds with natural pollination had a better fruit set (78%).

Table 1: Abundance of *A. cerana indica* in Pumpkin flowers (Location: Pollachi, Tamil Nadu, India: Season: Spring, 2023).

	Mean No. of foragers/flower/min ± S.D					
	15th day	**30th day**	**45th day**	**60th day**	**75th day**	**Mean**
Female flower	0.34±0.014	0.45±0.037	0.61±0.078	0.57±0.014	0.50±0.045	0.49
Male flower	0.59±0.035	0.76±0.021	1.01±0.071	0.88±0.051	0.81±0.014	0.81
Mean	0.469048	0.609524	0.816667	0.728571	0.659524	0.65

Note: *Mean of 10 plant observation; S.D: Standard Deviation

Table 2: Foraging activity of Indian bee in Pumpkin flowers (Location: Pollachi, Tamil Nadu, India: Season: Spring, 2023).

Mean time spent by a forager/flower/min in seconds± S.D						
	15th day	30th day	45th day	60th day	75th day	Mean
Male flower	3.08±0.52	4.91±0.62	6.58±0.38	5.91±0.52	4.66±0.94	5.03
Female flower	2.66±0.33	3.91±0.62	4.75±0.25	4.33±0.14	3.58±0.52	3.85
Mean	2.87	4.41	5.66	5.12	4.12	4.44

Note: *Mean of 10 plant observation; S.D: Standard Deviation

Table 3: Pollination efficiency index of *A. cerana indica* on pumpkin(Location: Pollachi, Tamil Nadu, India: Season: Spring, 2023).

Sr. No.	Insect species	Loose pollen adhering to the body of the insect		Pollinator abundance		Pollination efficiency index LP pi × PA pi	Pollinator Rank
		Number (LP)*	Performance score (LP pi)	No of insects (PA)**	Performance score (PA pi)		
1.	*A. florea*	6532	1.14	1.12	2.19	2.49	1
2.	*A. cerana indica*	7953	1.39	0.81	1.58	2.19	2
3.	*A. dorsata*	8739	1.53	0.11	0.21	0.32	4
4.	*Megachila lamia*	5321	0.93	0.51	1	0.93	3
	Total	28545		2.55			

*Mean of five observation under stereo zoom microscope
**Number of pollinator for 5 min/5 inflorescence (Mean of 10 days observation in Coimbatore field)

Table 4: Incoming and outgoing of *A. cerana indica* at hive entrance during peak flowering period (Location: Pollachi, Tamil Nadu, India: Season: Spring, 2023).

Foraging time	Incoming nectar foragers / 5 min	Incoming pollen foragers / 5 min	Outing bees / 5 min	Mean
07:00- 09:00h	33.92 (5.86)[a]	17.59 (4.25)[a]	38.69 (6.26)[a]	30.06
11:00- 13:00h	18.65 (4.37)[c]	9.84 (3.21)[b]	24.48 (4.99)[b]	17.65
15:00-17:00h	27.83 (5.32)[b]	11.08 (3.40) [b]	25.09 (4.98)[c]	21.33
Mean	23.46	12.83	29.42	
C.D. (P=0.05)	0.6784	0.6502	0.2473	0.5253

Note: * Mean of five observation, figures in parentheses are square root (X+0.5) transformed values. In column means followed by different alphabets are highly significantly different at 5% level LSD

Table 5: Colony growth parameter of *A. cerana indica* in pumpkin.

Days (15 days interval)	Sealed honey area(cm2)	% Increase in sealed honey area	Pollen storage area (cm^2)	% increase in pollen storage area	Sealed brood area(cm^2)	% increases in sealed brood area	Adult bee population	% increase of bee population
15	28	-	34	-	119	-	2054	-
30	43	53.57	47	38.23	145	21.84	2793	35.97
45	72	67.44	68	44.68	193	33.10	3122	11.77

Note: *Mean of two observations.

Table 6: Effect of different mode of pollination on pumpkin yield (Location: Pollachi, Tamil Nadu, India: Season: Spring, 2023).

Mode of pollination	No. of females flowers observed	No. of picking plants	No. of fruits /plants	Fruit weight(Kg)	% Increase in fruit weight	Yield of 10 plants (kg)	Yield (t/ha)	% Increase in yield (t/ha)
Pollination exclusion	70	0	0	0	-	0	0	-
		(0.7)[c]	(0.7)[c]	(0.7)[c]	-	0.7	-	-
Bee pollination(*A. cerana indica*)	70	2.83	3.32	3.50	3.85	113.49	39.72	14.74
		(1.82)[a]	(1.95)[a]	(2.00)[a]	-	10.67	-	-
Open pollination	70	2.6	3.12	3.37	-	98.9	34.615	-
		(1.76)[b]	(1.90)[b]	(1.96)[b]	-	9.96	-	-
S.E(d)		0.02	0.02	0.01				
C.D(P=0.05)		0.04	0.04	0.03				

Note: *Mean of five observation, **No fruit set was observed in pollinator exclusion. Figures in parentheses are square root of (X+0.5) transformed values. In columns, means followed by alphabet are highly significant different at 5% level LSD

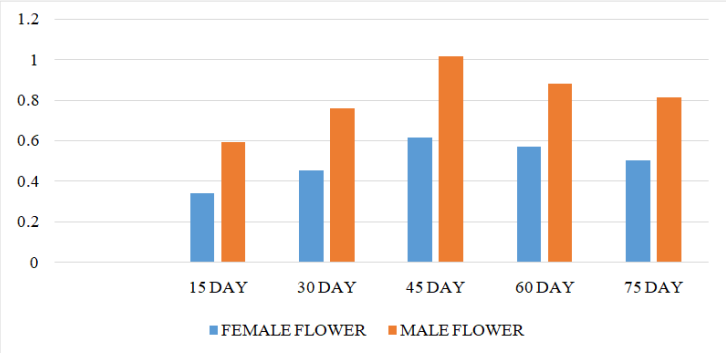

Fig. 1. Abundance of *A. cerana indica* in Pumpkin flowers (Location: Pollachi, Tamil Nadu, India: Season: Spring, 2023).

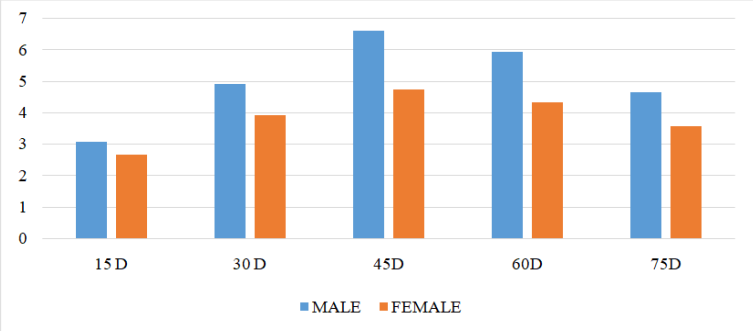

Fig. 2. Foraging activity of Indian bee in Pumpkin flowers (Location: Pollachi, Tamil Nadu, India: Season: Spring, 2023).

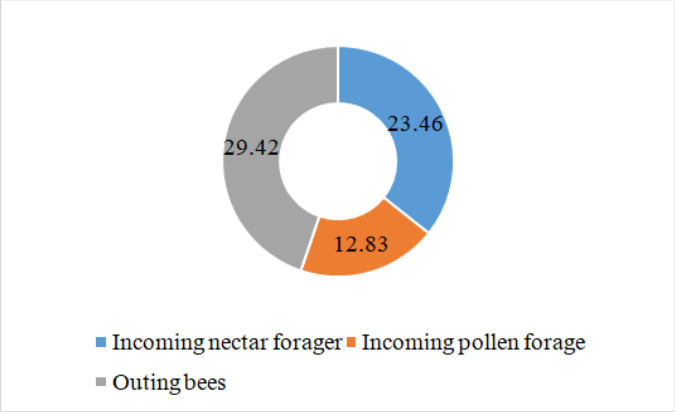

Fig. 3. Incoming and outgoing of *A. cerana indica* at hive entrance during peak flowering period (Location: Pollachi, Tamil Nadu, India: Season: Spring, 2023).

CONCLUSIONS

The cross pollination activity of *A. cerana indica*, an efficient pollinator of pumpkins, significantly enhances production outcomes. During the duration of the trial, the *A. cerana indica* colony growth parameter also began to rise. To increase the output of pumpkin and honey, planned pollination by bees with *A. cerana indica* is thus the best choice for farmers and beekeepers.

FUTURE SCOPE

The findings of this study's potential managed pollination method can be used commercially to improve fruits output, seed set, and fruit size.

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Conflict of Interest. None.

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