Sociobiology
An international journal on social insects

RESEARCH ARTICLE - BEES

Pollination Efficiency of the Indian Bee, *Apis cerana indica* Fab. in Bitter Gourd in Tamil Nadu, India

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Article History

Edited by
Evandro Nascimento Silva, UEFS, Brazil
Received 23 October 2024
Initial acceptance 19 June 2025
Final acceptance 05 July 2025
Publication date 23 October 2025

Keywords
Apis cerana indica; beekeeping; crop pollination; yield increase.

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Abstract

Cucurbits are cross-pollinated vegetables that rely on insect pollination for their reproduction and yield. Bitter gourd is a major cucurbitaceous plant widely cultivated in India. Though affected by several pests and diseases, the yield of bitter melon varies widely due to a pollination gap. Stingless bee – *Tetragonula iridipennis*, little bee – *Apis florea*, Indian bee – *Apis cerana indica,* and blue banded bees – *Amegilla zonata* are the most important pollinators of bitter gourd in the Tamil Nadu region of India. The present study was conducted to evaluate the effectiveness of the Asiatic honey bee, *Apis cerana indica*, in enhancing the yield of bitter gourd. *Apis cerana indica* is widely used by South Indian farmers, as it adapts to the tropical climate of the region. The honey bee colonies were introduced at 10% flowering and were maintained in the field until the last harvest. Colonies were kept amid the cropped field, covered with an insect net to prevent the escape of bees to nearby fields. Colonies were also kept without caging, as well as at a distance of 100 and 200 meters from the field. Control was maintained by not introducing any new colonies. The crop was cultivated using organic farming methods, with no use of synthetic chemical insecticides that could harm the honeybees and their activities. The increase in crop yield was up to 27.60% in the study area. The honey yield was also considered to study the increase in farmers' income. Bee hives placed inside the cropped area and at a distance of 100 m have shown better fruit and honey yields, and are therefore advisable for farmers.

Introduction

Pollination is the transfer of pollen from the male parts of the flower (the anther) to the female part (stigma) of the same or a different flower of the same plant or the different plants (Pokhrel, 2009). Not all flowering plants have the same pollination requirements. Cross-pollination is the transfer of pollen from flowers of one plant to the flowers of a different plant or variety. Many crops require or benefit from cross-pollination. Self-fertile plants can develop seeds and fruit when pollen is transferred from anthers of a flower to the stigma of the same or a different flower on the same plant. However, such plants are not necessarily self-pollinating. Insects may still be necessary or helpful in moving pollen to the stigmas. Some crop plants require specific insect pollinators at particular times, such as hawk moths on papaya, snout beetles on palm trees, blow flies on mangoes, and solitary bees on buckwheat (Pokhrel, 2009; Thapa et al., 2008). Pollinators provide an essential ecosystem service by producing seeds and fruit, as well as maintaining biodiversity. Properly pollinated plant exhibits larger seed vigor, longer viability, higher germination capacity, seedling vigor, pest resistance, and yield capacity. Mustard seeds contain higher oil content Subedi and Subedi (2019). Devkota (2000) concluded that pollination can significantly improve both the yield and quality of seeds in broccoli.

Pollination gap can be defined as "Differences in the rate of pollination services carried out by the pollinators in respective flowers that actually aids in a proper and good yield due to factors such as availability of flowers (Male: Female) and availability of a perfect efficient pollinator *i.e.* size of the pollinator that goes with the flower for easy and effective collection of pollen and or nectar so that the pollination service is provided effectively and sufficiently".

Cucurbits are monoecious (male and female flowers are borne at different positions on the same plant). The male-to-female flower ratio is about 25:1. Long days cause male flowers to bloom up to two weeks before female flowers (Palada & Chang, 2003). Anthesis occurs between 03:30 and 07:30, and the stigma remains receptive from 24 hours before to 24 hours after anthesis, being most receptive during the early hours of the day (Deshpande et al., 1979). The open position of the bitter gourd flowers makes them easily accessible to pollinators, allowing them to exploit the floral rewards. The high male-to-female ratio enables the production of a sufficient amount of pollen, resulting in effective pollination. A successfully pollinated flower starts to develop fruit on the second to fifth day after it has opened with petals detached, un-pollinated flowers dry up, and the ovary turns yellow on the fifth day (Deyto & Cervancia, 2009). The insects of the family Apidae are the most reliable agents for pollination. Among members of the Apidae family, honey bees are particularly important pollinators as they are capable of carrying pollen. In the process, the plants visited by them benefit (Tewari & Singh, 1983). Spraying flowering hormones to increase the number of flowers and therefore the fruits can increase the yield, but pollination of the flowers is challenging. Any material to increase the visit of pollinators can have a greater impact on harnessing pollination (Viraktamath & Anagoudar, 2002). The yield of cucumber varies widely due to pollination deficiency rather than fertilizer and pest related problems (Motzke et al., 2015).

The cucurbits' flowers are visited by a wide range of insect pollinators. Species of bees, wasps, ants, butterflies, flies, and beetles have been reported to provide pollination services to cucurbit flowers (McGregor, 1976; Free, 1993; Delaplane et al., 2000). Bees are the most studied and widely utilized pollinators for cucurbit crops worldwide, making the greatest contribution to the pollination of cucurbits (Delaplane et al., 2000; Garibaldi et al., 2013). They are used to provide pollination services for either open-field or protected environment cultivation (McGregor, 1976; Free, 1993; Delaplane et al., 2000).

Lingappa et al. (1999) studied the impact of pollination by *A. cerana indica* on the yield of watermelon and found a positive result, indicating an increase in yield. Pollination service by different species of honeybees in chow-chow and the difference in yield were studied by Eswarappa (2001). The impact of honey bee pollination on cucumber yield was studied by Pateel (2007), who reported a significant increase in the crop's yield. Subhakar et al. (2013) and Dorjay et al. (2017) reported *T. iridipennis, A. florea,* and *H. gutturosus* as major pollinators of bitter gourd. The impact of *A. cerana indica* on the blooming period has not been well understood, as only a very few studies have been undertaken in this regard. We tested the hypothesis that adding *A. cerana indica* hives inside or near crop fields would increase the yield of bitter gourd.

Materials and Methods

A field experiment was conducted at Kuttladampatti village (10.0962196 ºN and 77.9981232 ºE), Vaadipatti block, Madurai District during 2018 – 2019 to study the pollination efficiency of the Indian bee, *Apis cerana indica*. The local ruling variety was chosen for the experiment, as it is widely grown in the study area. The experiment was laid out in a Randomised Block Design (RBD) with six treatments and four replications. The distance between each treatment was maintained at a minimum of 2 km. This distance was maintained because the flight range of the Indian bees is up to 1500 m, and to ensure that bees from the hives kept in one experimental plot would not reach the other experimental plot. The size of the experimental plots was set at 25 cents for all the treatments and replications. The rate of bee hives introduced was ten per hectare (one bee hive for 25-cent area). The data were collected in each replication and later converted to a one-hectare unit. The treatment details are given below.

Treatment Details

T1: Crop caged with bee hives
T2: Hives placed in the field without a cage (open condition)
T3: Hives kept at a 100 m distance from the field boundary
T4: Hives kept at a 200 m distance from the field boundary
T5: Crop caged without bees (bee exclusion)
T6: Open pollination without any hives (control)

Agronomic practices were followed uniformly in all the experimental plots. The colonies were placed in the field at nighttime at 10% flowering. Nylon mosquito nets were used to cage the field. The field was caged by erecting a net elevated above the crop canopy (up to 1 – 2 feet) to ensure free air circulation and that the flower visitors have no disturbances. Hives were placed at the center of the field in treatments 1 and 2, whereas the colonies were placed at the planned distances from the field in treatments 3 and 4. First picking was carried out 55 to 60 days after sowing and continued up to 170 days after sowing. Every picking had an interval of 3 – 4 days. No insecticides were sprayed during the study period.

Foraging behaviour

The foraging behaviour of *A. cerana indica* was observed in different treatments to record the differences in foraging activity as influenced by the honey bee colonies. Foraging activity was observed by counting the bees in a randomly selected one square meter area at 06:00 – 08:00, 08:00 – 10:00, 10:00 – 12:00, 12:00 – 14:00, 14:00 – 16:00,

and 16:00 – 18:00 (since the bitter gourd flowers start opening at 03:00 of the day and open fully from 05:30 to 12:00) and averaged for No. of individuals/m^2/5 min (Free, 1993). The time spent by an individual in each flower was observed using a stopwatch at two-hour intervals, starting from 06:00 to 18:00.

Influence of bee pollination on the qualitative and quantitative parameters of bitter gourd

Observations were made on the number of fruits, length of fruits, width of fruits, weight of fruits, net plot yield, and yield per hectare (converted) to evaluate the efficiency of Indian bee pollination in the yield of bitter gourd.

In order to study the effect of bee pollination in enhancing the productivity and quality of bitter gourd, the following quantitative and qualitative parameters were recorded from each treatment.

Yield attributes

Number of fruits per plant – Was observed by counting the total number of fruits from randomly selected 10 plants during every picking and finally expressed as a number of fruits/plant.

Weight of the fruits – Was observed by weighing fruits drawn randomly from each treatment using an electronic balance.

Length and width of the fruits at the harvesting stage – Were measured by using a scale or measuring tape from randomly selected ten plants from the plot.

Net plot yield and yield per hectare – The fruits harvested from each plot were weighed separately during each picking, and the total fruit yield per plot was worked out. Net plot yield was later converted into total yield per hectare.

The difference in percentage was calculated using the formula,

$$\textbf{Per cent difference} = \frac{\text{Treatment} - \text{Control}}{\text{Treatment}} \times 100$$

Statistical analysis

The values in the table represent the mean values of all replications for each respective treatment. The statistical analyses of the data obtained were done as described by Gomez and Gomez (1984). The field data was subjected to statistical analysis by RBD. The mean values were transformed using the square root and compared using the Least Significant Difference (LSD) test at a 5% probability with AGRES to assess the best treatment for improving pollination efficiency in *A. cerana indica.*

Results

Abundance of Indian bees in bitter gourd

Observations on the abundance of *A. cerana indica* influenced by the introduced bee hives in bitter gourd are presented in Fig 1. In general, the activity of *A. cerana indica* started from 06:00 and reached its peak during 08:00 – 10:00. The activity started declining gradually thereafter, with the least activity occurring between 16:00 and 18:00. The mean abundance of bees in each treatment varied from 11.94 bees/m^2/5 min in caged bee hives to 1.14 bees/m^2/5 min in open pollination. The detailed data on the abundance of bees is explained here.

Caged bee hives and bee hives placed inside without a cage were on par at 06:00 – 08:00. The abundance of the bees was 17.08 and 17.61 bees/m^2/5 min. Hives kept at 100 m followed in the next rank with 11.85 bees/m^2/5 min, which was followed by hives kept at 200 m and open pollination, with 7.75 and 2.63 bees/m^2/5 min, respectively. During 08:00 to 10:00, crops caged with bee hives and crops with bee hives in open condition were on par with 19.15 and 19.44 bees/m^2/5 min and crops with colonies placed at 100 m and 200 m distances were on par with 11.24 and 8.09 bees/m^2/5 min, which was followed by open pollination 3.04 bees/m^2/5 min. The activity of bees started declining gradually after 10:00 in all treatments. Between 10:00 and 12:00, crops caged with bees outperformed the other treatments, with 14.47 bees/m^2/5 min, followed by plots with hives placed inside the field in open conditions, with 11.13 bees/m^2/5 min. Furthermore, plots with hives kept at 100 and 200 m showed an abundance of 5.38 and 3.81 bees/m^2/5 min respectively, while open pollinated crop attracted 0.88 bees/m^2/5 min (Fig 1).

Abundance of the bees between 12:00 – 14:00 was 12.13 bees/m^2/5 min in crops caged with bee hives and 7.44 bees/m^2/5 min in crops with hives placed inside under open conditions. Crops with hives at 100 m and 200 m attracted 2.28 and 1.24 bees/m^2/5 min, respectively, while the open-pollinated crop attracted 0.19 bees/m^2/5 min. In the evening hours, the abundance of bees visiting bitter gourd flowers was still lower with 5.48, 3.44, 2.50, 1.64, and 0.09 bees/m^2/5 min in crops caged with bee hives, crops in open condition with hives, crops with hives kept at 100 m and 200 m, and open pollination respectively. Between 16:00 – 18:00, the bee activity ranged from 3.33 bees/m^2/5 min in crops caged with bees to 0.02 bees/m^2/5min in open pollination (Fig 1).

Time spent by Indian bees on bitter gourd

The time spent by *A. cerana indica* in bitter gourd flowers follows the same trend as that of the abundance of bees. The bees spent the maximum time from 06:00 to 10:00, which decreased thereafter till 18:00. The time spent by *A. cerana indica* in bitter gourd flowers is presented in Fig 2. The mean time spent by the bees varies as much as 16.1 seconds/flower/5 min in crops caged with bees, 13.43 seconds/flower/5 min in plots with hives placed inside the field without cages, and 10.73 and 6.47 seconds/flower/5 min in crops with hives placed at 100 m and 200 m. The bees spent only 4.22 seconds/flower/5 min in open condition (Fig 2).

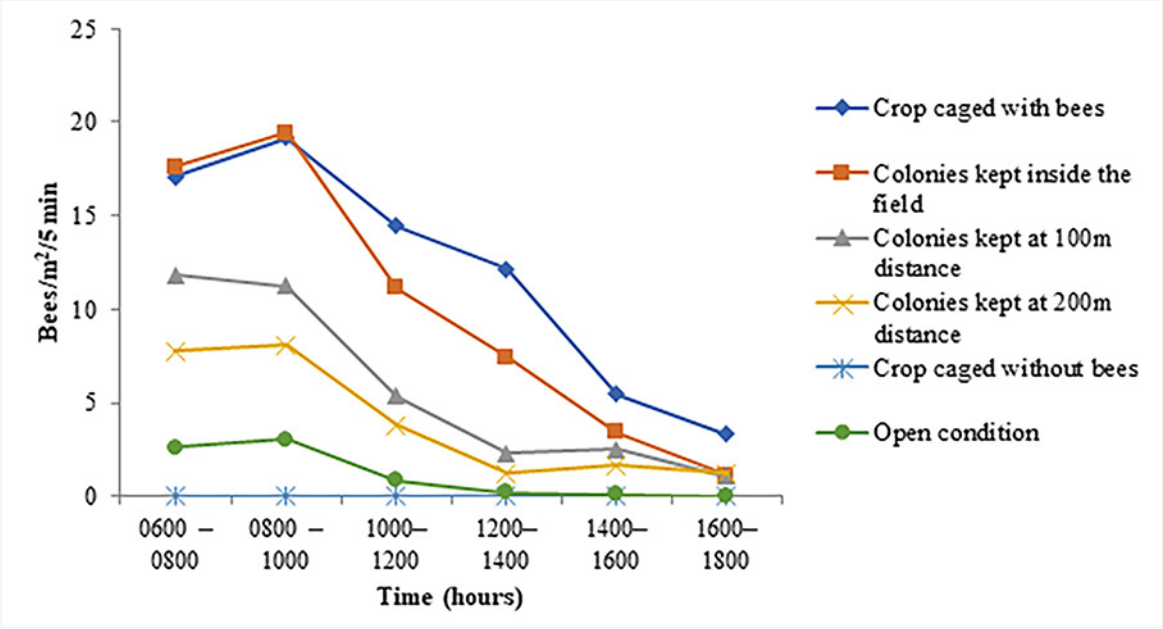

Fig 1. Foraging activity (abundance) of Indian bees as influenced by bee colonies.

The bees spent the maximum time in each flower during 06:00 – 08:00 was 37.25 seconds/flower/5min in crops caged with bee hives, 30.86 seconds/flower/5 min in plots with hives placed inside the field without cages (on par) and 21.18, 13.41 and 11.08 seconds/flower/5 min in plots with hives placed at 100 and 200 m distances and open pollination. The time spent by the bees between 08:00 – 10:00 was 32.50 seconds/flower/5 min in crops caged with bees and 29.25 seconds/flower/5 min in plots with hives placed inside the field in open condition and 22.47 and 13.98 seconds/flower/5 min, respectively, in crop with hives placed between 100 and 200 m distances. The average time spent by the bees between 10:00 – 12:00 in each flower was 13.50, 11.95, 10.72, 5.98 and 2.41 seconds/flower/5 min in crops caged with bee hives, crops with hives placed in the field in open, crops with hives placed at 100 and 200 m distances and open pollinated crop respectively (Fig 2).

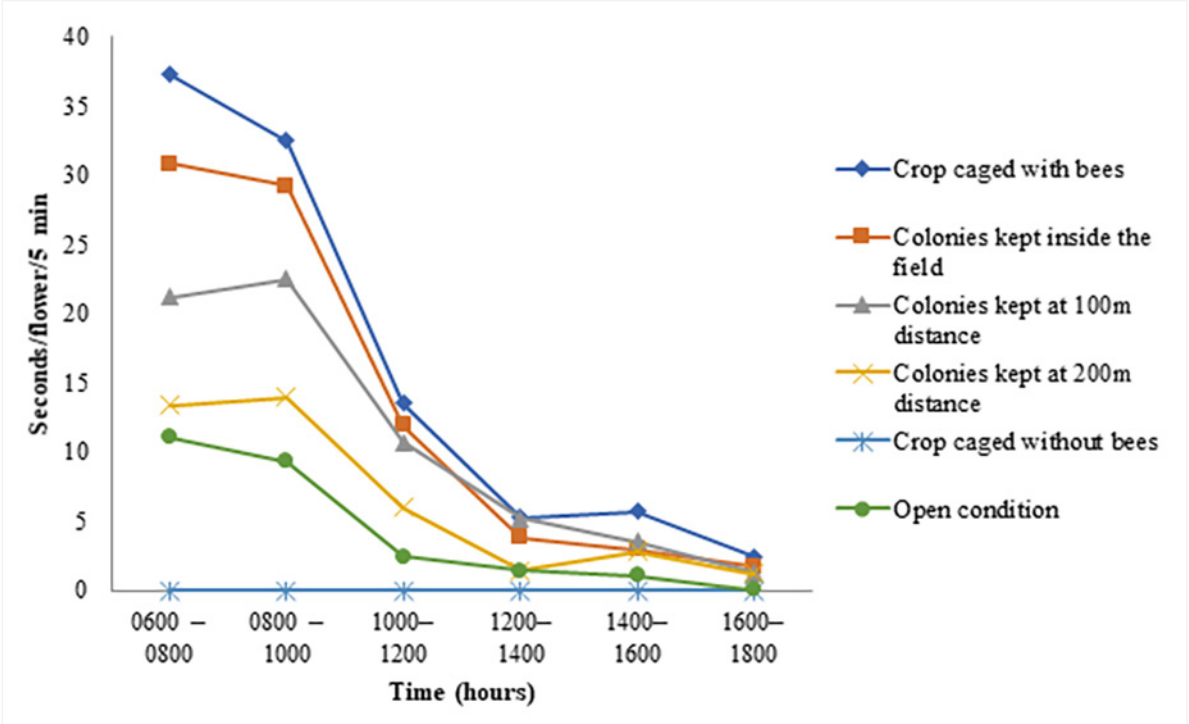

Fig 2. Time spent by Indian bees in the flowers of *M. charantia* for every two hours from 06:00 – 18:00 as influenced by bee colonies placed in the field.

The time spent by the bees in mid-day periods (12:00 – 14:00) was in the range of 5.25 seconds/flower/5 min in crops caged with bee hives and 1.40 seconds/flower/5 min in control, while it was 5.71 and 1.08 seconds between 14:00 – 16:00, respectively, for the same. During the evening hours 16:00 – 18:00, the bees spent 2.44 seconds/flower/5 min in crops caged with bee hives, 1.70 seconds/flower/5 min in plots with hives placed inside the field without cages and 1.28 and 1.24 seconds/flower/5 min in crops with hives placed at 100 and 200 m, whereas the bees spent only 0.05 seconds/flower/5 min in open condition (Fig 2).

The data regarding the influence of bee pollination on the qualitative and quantitative parameters of bitter gourd (yield attributes) are presented in Table 1. The results are explained here.

Number of fruits/plant

The number of fruits/plants was significantly higher in the plots with hives placed inside the field without cages (9.90 fruit), which accounted for an increase in the number of fruits to the tune of 55.35 and 32.43% over the crop caged without bees and open pollinated crop (Table 1). It was on par with crops caged with bee hives (8.92 fruit), which recorded 50.44 and 25.00 percent increase over the crop caged without bees and open pollination. Crop with hives at 100 m distance (8.34 fruit) while crop with hives at 200 m distance (7.17 fruit) has shown 38.35 and 6.69% increase over crop caged without bees and open pollination, while open pollinated plot without bee hives evidenced 33.93 percent increase over crop caged without bees (6.69 fruit) (Table 1).

Length of the fruits

The length of the fruit was highest in plots with bee hives placed inside the field without cages (29.44 cm), which presented 41.85% and 30.70% increases over the crop caged without bees and open pollination, respectively. Crop caged with bee hives and crops with hives at 100 m were on par, in which the fruit length was 26.92 cm and 25.14 cm. It accounted for a 36.40% and 31.90% increase over crops caged without bees, and 24.22% and 18.85% over open pollination (Table 1).

Width of the fruits

The width of the fruit has not shown much variation within the treatments. Plots with bee hives placed inside the field without cages were significantly superior and recorded a maximum width of 14.32 cm (Table 1). The following treatments, *viz.,* crop caged with bee hives (13.77 cm), crops with hives at 100 (13.52 cm) and 200 m (12.72 cm) distances, were on par with each other. The plots with bee hives placed inside without cages accounted for a 26.88 and 14.59% increase over the crop caged with bees and open-pollinated crop. The width of the fruit was 12.23 cm in open pollination (Table 1).

Weight of the fruits

Plots with hives placed inside the field without cages recorded significantly higher fruit weight (201.60 g) against 188.40 g in the crop caged with bees. Crops with hives kept at 100 and 200 m distances recorded 178.60 and 171.00 g, while crops in open pollination recorded 163.2 g against 138.4 g in crops caged without bees. Crops caged with bee hives and crops with hives at 100 m distance were on par with each other (Table 1).

Net plot yield (quintal)

The highest net plot yield was recorded in the crops with hives placed inside the field without cages (23.03q). It contributed a 48.12% increase over caged without bees and a 27.60% increase over open pollination. This was followed by crop caged with bee hives (21.15q) with an increase to the tune of 43.79 and 21.16% over crop caged without bees and open pollination (Table 1). This was followed by crops with hives kept at 100 and 200 m distances (20.06 and 19.16q). The increase of yield was 16.89 and 12.95% over open pollination and 37.92 and 28.69% over crops caged without bees. The open-pollinated plot presented a 28.69% increase in net plot yield compared to the plot caged without bees. Yield obtained in crops with hives placed inside the cage and crops in open conditions without a cage were on par. Crops with hives at 100 and 200 m were also comparable to each other (Table 1). All the treatments were statistically significant over the plot caged without bees (11.89q).

Yield per hectare (converted)

A similar trend was observed in yield per hectare converted based on the net plot yield. Crops with hives placed inside the field without a cage yielded the highest, at 219.84q/ha, compared to the other treatments. Crops caged with bee hives (201.90q/ha) were on par with crops having hives placed at 100 m (191.53q/ha). Crops with hives placed at 100 m were also on par with the crops in hives placed at 200 m distance (182.86q/ha). This was followed by open pollination and crops caged without bees (159.17 and 113.52q/ha) (Fig 3).

Honey yield

Honey was harvested from all four treatments, aided by bee hives. The first harvest was taken up approximately three months after placing the hives in the field, and the second was 60 days after the first harvest. The honey yield was significantly higher (1565.00 g) from the hives kept in open conditions inside the field. Plots with hives placed at 100 m (1452.50 g) and 200 m (1435.00 g) distances were comparable to each other. Minimum yield (436.25 g) was obtained in plots with hives in caged conditions (Fig 4).

In general, the foraging activities of the bees, differences in yield parameters, and qualitative characteristics of the fruit are more positive in treatments 1, 2, 3, and 4 compared to those of 5 and 6. This shows the influence of bee pollination on the yield and quality of the produce.

Table 1. Influence of bee pollination on the qualitative and quantitative parameters of bitter gourd.

S. №	Treatments	Number of fruits/plant*	% increase over caged without bees	% increase/ decrease over OP (control)	Length of fruit (cm)*	% increase over caged without bees	% increase/ decrease over OP (control)	Width of the fruit (cm)*	% increase over caged without bees	% increase/ decrease over OP (control)
T1.	Crop caged with bees	8.92 (2.99)^{ab}	50.44	25.00	26.92 (5.19)^{b}	36.40	24.22	13.77 (3.71)^{ab}	23.81	11.18
T2.	Colonies kept inside the field	9.90 (3.15)^{a}	55.35	32.43	29.44 (5.43)^{a}	41.85	30.70	14.32 (3.78)^{a}	26.88	14.59
T3.	Colonies kept at 100 m distance	8.34 (2.89)^{b}	47.00	19.78	25.14 (5.01)^{b}	31.90	18.85	13.52 (3.68)^{ab}	22.56	9.54
T4.	Colonies kept at 200 m distance	7.17 (2.68)^{c}	38.35	6.69	22.40 (4.73)^{c}	23.34	8.92	12.72 (3.57)^{ab}	17.69	3.85
T5.	Crop caged without bees	4.42 (2.10)^{d}	-	-51.35	17.12 (4.14)^{e}	-	-19.16	10.49 (3.24)^{c}	-	-16.59
T6.	Open condition (control)	6.69 (2.59)^{c}	33.93	-	20.40 (4.52)^{d}	16.07	-	12.23 (3.50)^{b}	14.39	11.18
	S.Ed	0.08			0.09			0.11		
	CD (0.05)	0.17			0.18			0.24		

S. №	Treatments	Weight of the fruit(g)*	% increase over caged without bees	% increase/ decrease over OP (control)	Net plot (25 cents) yield (quintals)*	% increase over caged without bees	% increase/ decrease over OP	Yield per hectare (q/ha) (converted)	% increase over caged without bees	% increase/ decrease over OP (control)
T1.	Crop caged with bees	188.4 (13.73)^{ab}	26.5	13.37	21.15 (4.60)^{b}	43.79	21.16	201.90 (14.21)^{b}	43.77	21.16
T2.	Colonies kept inside the field	201.6 (14.20)^{a}	31.35	19.05	23.03 (4.80)^{a}	48.12	27.60	219.84 (14.83)^{a}	48.36	27.60
T3.	Colonies kept at 100 m distance	178.6 (13.36)^{bc}	22.51	8.62	20.06 (4.48)^{bc}	40.73	16.89	191.53 (13.84)^{bc}	40.73	16.90
T4.	Colonies kept at 200 m distance	171.00 (13.08)^{bc}	19.06	4.56	19.16 (4.38)^{c}	37.92	12.95	182.86 (13.52)^{c}	37.91	12.96
T5.	Crop caged without bees	138.4 (11.76)^{d}	-	-17.92	11.89 (3.45)^{e}	-	-40.23	113.52 (10.66)^{e}	-	-40.21
T6.	Open condition (control)	163.20 (12.78)^{c}	15.19	-	16.67 (4.08)^{d}	28.69	-	159.17 (12.62)^{d}	28.68	-
	S.Ed	0.37			0.07			0.20		
	CD (0.05)	0.77			0.14			0.42		

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

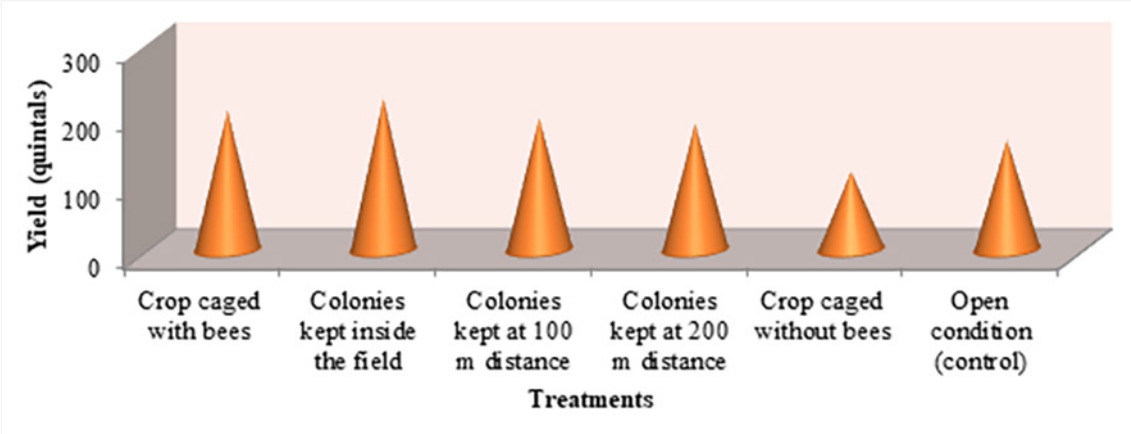

Fig 3. Influence of *A. cerana indica* pollination in yield per hectare (converted).

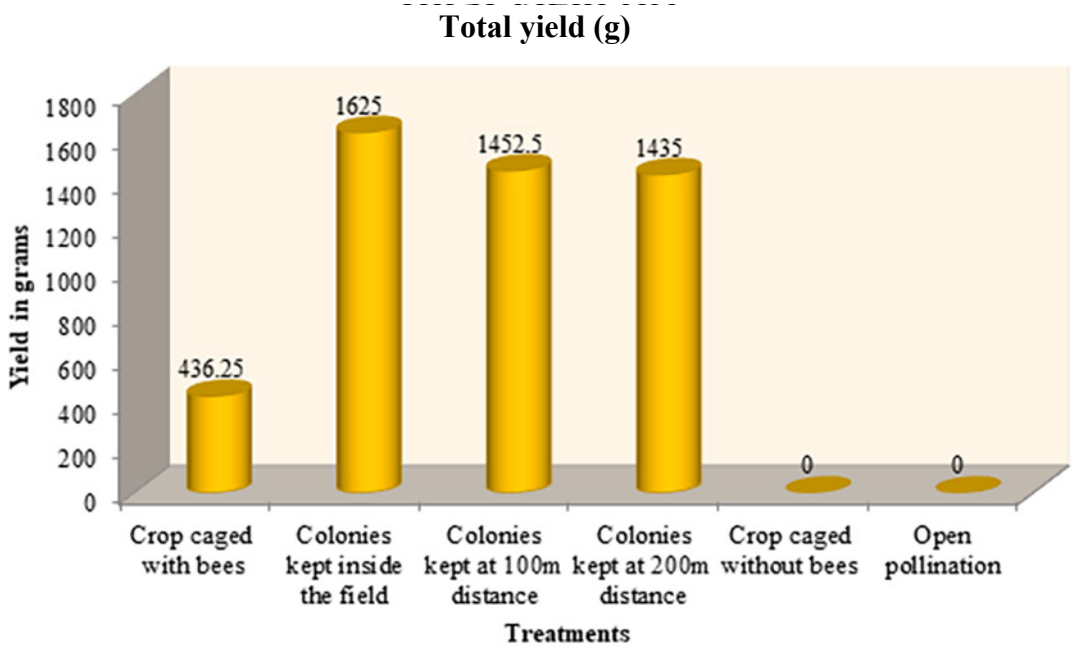

Fig 4. Influence of planned pollination on honey yield (g).

Discussion

Our research found a maximum activity of Indian bees in the early morning hours up to 10:00 with a peak activity between 08:00 and 10:00, confirming the earlier findings of many authors (McGregor & Todd, 1952; Wolfenbarger, 1962; Maynard et al., 1992) who also reported the peak activity of Indian bees between 08:00 – 10:00. Cervancia and Forbes (1993) observed increased bee visits when honey bee colonies were introduced into the cropped field, while the current result also shows increased bee visits in plots with introduced bee hives. Our findings align with the latest report by Vasanthakumar et al. (2018), who placed honey bee colonies at varying distances from mango trees and observed increased bee visits and yield.

The time spent by *A. cerana indica* in bitter gourd flowers follows the same trend as that of the abundance of bees. The bees spent the maximum time from 06:00 to 10:00 hours, after which the time decreased. Our findings are in close agreement with the reports of Dorjay et al. (2017) on bitter gourd, who also reported the same findings for *Apis mellifera*. The reports of Vasanthakumar et al. (2018) align with the findings of our research, which also reported the same in mango.

Santos et al. (2008) also experienced an increase in yield with pollination by stingless bees in greenhouse cucumber. In mango, Vasanthakumar et al. (2018) also reported an increased yield through planned bee pollination by placing Indian bee colonies at specific distances within the orchard. The above findings prove the trueness of our research output, the highest net plot yield in plots with a bee hive kept in open condition, which contributed a 48.12% increase over caged field without any bee hives and a 27.60% increase over open pollination.

Pollen deposition on stigma and, therefore, fruit size and weight will be enhanced by adding bee colonies in the field. This is due to the availability of more bees in the field (Stapleton et al., 2000). The yield was higher in plots with hives placed inside in open conditions than in crop caged with bee hives. This may be due to a reduced rate of pollination, which would have been supplemented by other pollinators, or changes in microclimate within the caged field. This report was given by Cervancia and Forbes (1993). The yield difference between crops with hives placed at 100 and 200 m might be due to other crops available in the location, which bees might prefer.

The honey yield was significantly higher (1643.75g) from the hives kept in open conditions inside the field. A lesser yield of honey from colonies placed inside the cages might be due to the microclimate prevailing within the cage or a lack of sufficient food sources. At the same time, the bees in open conditions i.e., Colony kept inside the field in open condition. Hives kept at 100m and 200 m distances from the field had been allowed to forage on crops and wild flowers available around the experimental field. During the second harvest, guava trees in the research location started blooming, which might serve for additional honey yield.

Conclusion

The abundance of bees visiting the flowers, the time spent by the bees in flowers, and the increase in the yield of bitter gourd were higher when the hives were placed inside the field, and they declined when the distance of the hive from the field was greater. From the above results, it is concluded that honey bee hives can be introduced in the fields to increase the yield of bitter gourd and so improve the livelihood of the farmers.

Acknowledgement

We thank the farmers of Kutladampatti village and the Department of Entomology, Agricultural College and Research Institute, TNAU, Madurai, for their support in conducting the research.

Authors' Contribution

Yogapriya A: Conceptualization, methodology, software, validation, formal analysis, investigation, data curation, resources, writing: original draft, writing: review & editing, visualization, project administration, funding acquisition.
B. Usharani: Conceptualization, methodology, validation, formal analysis, investigation, resources, writing: review & editing, visualization, supervision
K. Suresh: Conceptualization, resources, writing: review & editing, supervision

Data availability statement – Data available as supplementary material.

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