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Role of *Apis cerana* Fab. in sunflower pollination

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Abstract

Sunflower is cross pollinated crop which attracts lots of pollinators for pollination services. One among them is the Indian bee, *Apis cerana* Fab. which is widely domesticated in Southern part of India. These are also the Eastern honey bees which belongs to the order Hymenoptera and family Apidae. The management practices are easy with this particular bees. Henceforth, sunflower pollination was studied concerned to *A. cerana* for better yield and quality. In this study, the sunflower was enclosed with *A. cerana* in a closed condition to avoid other pollinator intervention, in the other treatment sunflower were maintained in open pollinated condition and a control was set where pollinator were restricted. The results recorded significantly higher in both quantitative and qualitative parameters with open pollinated sunflower followed by sunflower enclosed with *A. cerana* when compared to the sunflower enclosed to avoid pollination. Overall, *A. cerana* can be recommended for the pomegranate pollination for better quality and quantity of sunflower.

Keywords: *Apis cerana*, sunflower pollination, *Helianthus annuus* L

Introduction

Sunflower (*Helianthus annuus* L.) commonly known as Surajmukhi or Suryakanti belongs to family Asteraceae and is native to Central America. The area under sunflower cultivation in India was 344.2 thousand ha. with an annual production of 240.7 thousand tonne and productivity of 699 Kg/ha (Anon., 2018) [4].

In the recent trends use of pollinators is considered to be one of the low cost technique, reliable and eco-friendly method to improve the qualitative and quantitative factors of cross-pollinated crop. Honey bees are considered to be the best pollinating agents because of their optimum body size, thoroughness, hairiness, steadfastness, floral fidelity and manageable populations (Kumar *et al.*, 2020) [6]. Being more flower-constant and polytrophic in nature, they can effectively pollinate a large number of crops. "About one-third of the human diet comes from insect-pollinated plants, and honey bees account for 80 percent of pollination" (Anon., 1995) [3]. *A. cerana* bees which are native to Southern, Southeastern, and eastern Asia. It has well adopted and spread widely across South India. The caring and management practices are easy with this particular bees. Henceforth, sunflower pollination was studied concerned to *A. cerana* for better yield and quality. Even sunflower rewards bees with a good quantity of nectar and pollen that attract a large number of pollinators. Even though pollination activity is performed by other pollinators, *Apis* and Non-*Apis* bees account for a major share among them. Though Karnataka is one of the major states growing sunflower, there is no recommendation of *A. cerana* colonies for optimum pollination for maximizing the yield. Keeping this in view, the present investigations were made with the following objectives

1. Studying the different modes of pollination in sunflower
2. Qualitative and quantitative analysis of sunflower under different modes of pollination

Material and methods

Field investigations were carried out at the Zonal Agricultural Research Station, GKVK, Bangalore. The sunflower Hybrid KBSH-44 was sown by following the recommended package of practices of UAS, Bangalore during kharif 2017. Observations were made on foraging pattern of the different pollinators.

The number of bees visited was recorded for sunflower enclosed with *A. cerana* colony. Flowering period of KBSH-44 ranged from between 8 to 10 days. Flowering was initiated on 21st November 2017 and flowering period continued till 29th November 2017.

Observations were recorded when <25% (2nd day), 25-50% (4th day), 51-75% (6th day) and > 75% (8th day) disc florets opened. The flower opening in sunflower follows “centripetal flower opening” (opening from the border of the capitulum and proceeding towards the centre).

Ten bees of *Apis cerana Fab.* were collected near hive kept inside the enclosure while returning from foraging for observing the relative quantity (mg/bee) of pollen deposits on their corbicula (Pollen basket). The bees were collected in plastic vials and were immediately transferred to portable icebox to inactivate them. Once the pollen load gets separated from the bee body, pollen load and weight of the bee was recorded using electronic balance. The ratio of bee body and pollen load was calculated using formula presented below

$$\text{Ratio of bee body weight and pollen wei} = \frac{\text{Weight of bee body (mg)}}{\text{Pollen load weight (mg)}}$$

Quantitative parameters

The capitula of sunflower (10 heads) were bagged immediately after complete seed set. With the threshed seeds, the total count of seeds in the sunflower capitulum, number of filled and unfilled seeds, total individual seeds from each treatments, test weight of all the three replications were recorded. 100 seeds were selected randomly from each treatment and dried thoroughly and de-husked for calculating husk percentage, kernel percentage and kernel to husk ratio. Randomly seeds were selected from each treatment to calculate the seed index. The mean weight of seeds from ten capitulum from each treatments was taken and finally the yield was converted into Kg/ ha.

Qualitative yield parameters in sunflower

With 100 filled seeds the mean weight was calculated and was expressed in g/100ml, per cent oil content for 25-30g of seeds was carried out at Zonal Agricultural Research Station, GKVK, UAS Bangalore by using NMR (Nuclear Magnetic Resonance).

Two months after seeds were harvested seed germination test was carried out. Fifty seeds from each treatment were collected and were placed on germination paper and kept in the germination chamber at 20 °C and 90 percent relative humidity. The germination count was made 7 days after incubation. The data so obtained were converted to the percentage. The data were subjected to statistical analysis to draw the inference.

For evaluating vigour of seedling, ten seedlings from each treatment were selected randomly and the length of shoot and root was measured. The data were averaged for each treatment and then subjected to statistical analysis to draw the inference.

$$VI = RL + SL \times GP$$

Where in, VI= Vigour Index; RL= Root length; SL=Shoot length; GP=Germination percentage The observation was made by weighing 1000 dried seeds drawn randomly from each treatment using an electronic balance. The data were subjected to statistical analysis to draw the inference.

Statistics: Descriptive statistics was done using CCARI-WASP software.

Result and Discussion

Abundance of *A. cerana* pollinators during different per cent disc florets opening

The observations were recorded when < 25%, 26-50%, 51-75% and at >75% of disc florets opened (disc florets near periphery) out of 10 flowers from *A. cerana* treatment the mean was worked out and are presented in Table 1 & Figure 1. At < 25%, the mean number of pollen collectors was 0.88 bees/ capitulum/ 5 min. *A. cerana* showed peak time of activity between 11.00 to 12.00hrs (1.81 bees/ capitulum/ 5 min). Nectar collecting bees attained their peak during afternoon hours between 15.00 to 16.00hrs (2.38 bees/ capitulum/ 5 min) with a mean of 1.32 bees. The mean number of *A. cerana* foragers (Pollen and nectar foragers) visited was 2.19 bees/ capitulum/ 5 min. Both pollen and nectar foragers showed peak activity time from 11.00 to 12.00 (3.63 bees/ capitulum/ 5 min).

When 26- 50% of disc florets opened *A. cerana* foragers recorded two peak activity period viz., first between 10.00 to 11.00 hrs (4.06 bees/ capitulum/ 5 min) and second during 16.00 to 17.00 hrs (3.42 bees/ capitulum/ 5 min) with an average of 2.87 bees/ capitulum/ 5 min. Pollen foragers attained their peak activity between 10.00 to 11.00 hrs (2.41 bees/ capitulum/ 5 min) with a mean of 1.21 bees/ capitulum/ 5 min. The peak activity of nectar collectors was recorded between 15.00 to 16.00 hrs (2.82 bees/ capitulum/ 5 min) with an average of 1.66 bees/ capitulum/ 5 min.

When 51- 75% of disc florets opened the both pollen and nectar (total) foragers of *A. cerana* recorded two peak activities between 11.00 to 12.00 hrs (5.5 bees/ capitulum/ 5min) and 16.00 to 17.00 hrs (4.86 bees/ capitulum/ 5min) with a mean of 3.73 bees/ capitulum/ 5min (Table 7). The mean pollen foragers visiting sunflower was 1.68 bees/ capitulum/ 5min. Pollen foragers visited more frequently during morning hours between 11.00 to 12.00 hrs (3.44 bees/ capitulum/ 5min). The peak nectar forager's activity was recorded between 16.00 to 17.00 hrs (3.82 bees/ capitulum/ 5min) with an average of 2.05 bees/ capitulum/ 5min.

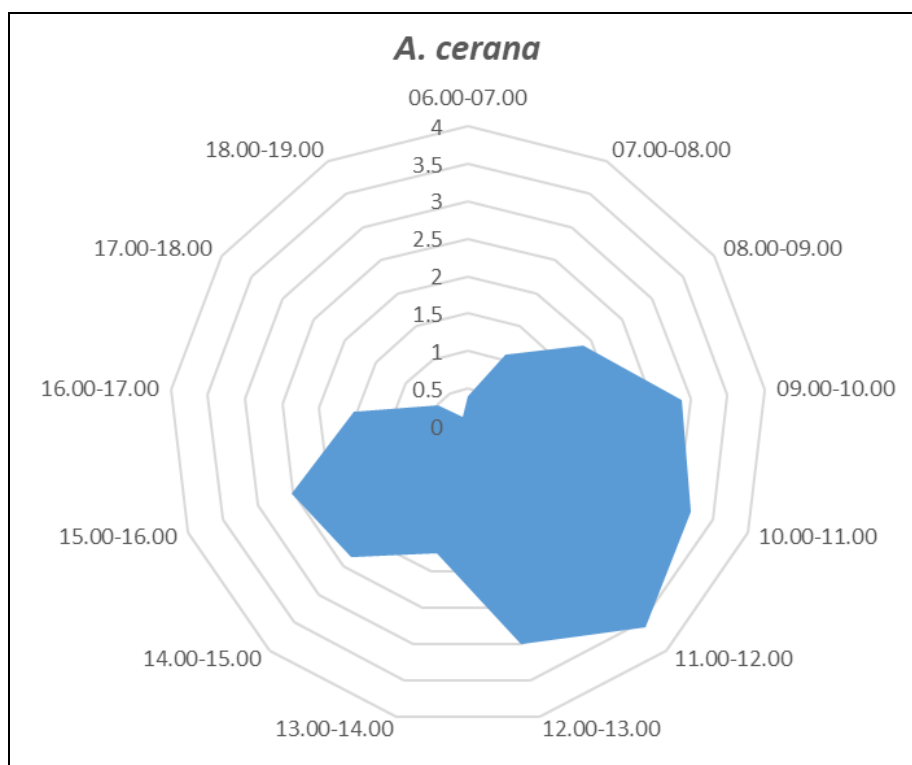
During full bloom, *A. cerana* foragers recorded two peak activities. The first peak was observed at morning 11.00 to 12.00 hrs with 5.59 bees/ capitulum/ 5min and a second peak between 16.00 to 17.00 hrs (5.79 bees). The mean number of foragers was 4.25 bees/ capitulum/ 5 min. Maximum number of pollen foragers was observed between 11.00 to 12.00 hrs (3.52 bees/ capitulum/ 5 min) with an average of 1.91 bees. The nectar foragers attained their peak during afternoon hours between 16.00 to 17.00 hrs (4.71 bees/ capitulum/ 5min) with mean visitors of 2.34 bees/ capitulum/ 5 min.

Similar study was carried out with cv. KBSH-53, where the report says that During the full bloom stage of the crop, *A. dorsata*, *A. cerana*, *A. florea*, *Tetragonula* sp., *Xylocopa latipus*, *X. aestuans* and *Xylocopa* sp were major pollinators. *A. dorsata* foraged for all the 12 daylight hours, while *A. cerana* was active for 10 hrs. and *A. florea* for only 8 hrs. The peak activity of majority of bee species was observed during 11.00-12.00 hrs. however, peak activity of *X. latipus* was observed during 16.00-17.00 hrs (1 bee/ capitulum) and *T. iridipennis* was during 11.00 to 12.00 hrs (0.50 bees/ capitulum) (Basavaraj *et al.*, 2016) [5]. The *A. florea* and *A. cerana indica* were the most abundant pollinators on sunflower and these species visited the capitulum most intensively during 06.00 to 11.00 hrs. whereas during 12.00 to 14.30 hrs. their activity was limited (Rangarajan *et al.* 1974) [8].

Table 1: Abundance of *A. cerana* pollinators during different per cent disc florets opening (Mean No./ Capitulum/ 5min.)*

| Time | <i>A. cerana</i> | | | | | | | |
|-------------|------------------|--------|---------|--------|---------|--------|--------|--------|
| | < 25% | | 26- 50% | | 51- 75% | | > 75% | |
| | Pollen | Nectar | Pollen | Nectar | Pollen | Nectar | Pollen | Nectar |
| 06.00-07.00 | 0.28 | 0.53 | 0.85 | 0.81 | 0.96 | 0.78 | 1.27 | 0.90 |
| 07.00-08.00 | 0.93 | 0.71 | 1.32 | 1.04 | 1.48 | 0.83 | 1.77 | 1.05 |
| 08.00-09.00 | 1.02 | 0.90 | 1.62 | 1.36 | 2.18 | 1.29 | 1.95 | 1.6 |
| 09.00-10.00 | 1.38 | 1.26 | 1.94 | 1.51 | 2.61 | 1.54 | 2.37 | 1.72 |
| 10.00-11.00 | 1.55 | 1.48 | 2.41 | 1.65 | 2.85 | 1.75 | 2.75 | 1.88 |
| 11.00-12.00 | 1.81 | 1.82 | 1.77 | 1.83 | 3.44 | 2.06 | 3.52 | 2.07 |
| 12.00-13.00 | 1.07 | 2.06 | 1.27 | 1.74 | 1.71 | 2.21 | 3.41 | 2.16 |
| 13.00-14.00 | 0.98 | 2.22 | 1.05 | 1.62 | 1.57 | 2.87 | 2.17 | 2.55 |
| 14.00-15.00 | 0.86 | 2.16 | 1.02 | 2.31 | 1.30 | 3.39 | 1.53 | 3.12 |
| 15.00-16.00 | 0.62 | 2.38 | 0.52 | 2.82 | 1.27 | 3.55 | 1.29 | 3.58 |
| 16.00-17.00 | 0.37 | 1.00 | 0.83 | 2.59 | 1.04 | 3.82 | 1.08 | 4.71 |
| 17.00-18.00 | 0.40 | 0.32 | 0.66 | 1.44 | 0.66 | 1.67 | 0.96 | 3.35 |
| 18.00-19.00 | 0.12 | 0.27 | 0.43 | 0.84 | 0.71 | 0.94 | 0.74 | 1.72 |
| Total | 11.39 | 17.11 | 15.69 | 21.56 | 21.78 | 26.70 | 24.81 | 30.41 |
| Mean | 0.88 | 1.32 | 1.21 | 1.66 | 1.68 | 2.05 | 1.91 | 2.34 |
| SD | 0.51 | 0.76 | 0.59 | 0.62 | 0.86 | 1.05 | 0.90 | 1.09 |

*Mean of 10 plants for entire flowering period

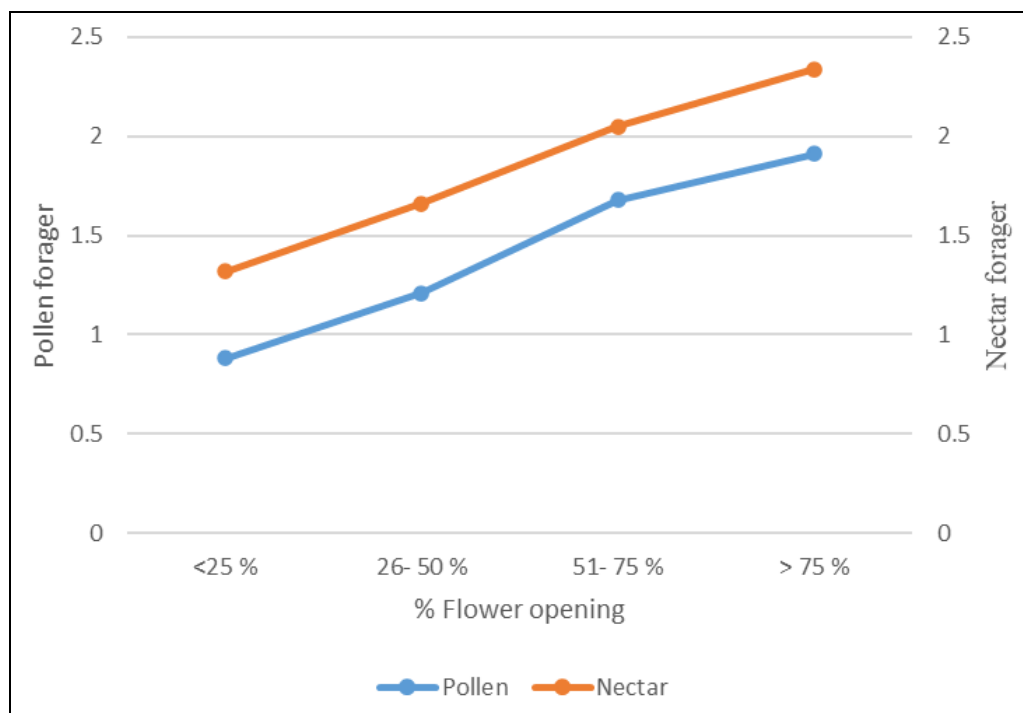
**Fig 1:** Mean time spent by *Apis cerana* Fab. Fab. foragers for collection of pollen/nectar/sunflower head during different time intervals (sec/capitulum)

The maximum number of nectar foragers of *A. cerana* was recorded during >75% disc florets opening stage (2.34 bees/capitulum/ 5min) and minimum was recorded during <25 percent florets opening (1.32 bees/ capitulum/ 5min) with a mean of 1.84 bees/ capitulum/ 5min. for entire flowering period. Maximum of 0.28 *T. iridipennis* nectar foragers visited during 56- 75 and >75 percent florets opening and minimum foragers were recorded when <25 and 26-50 percent florets opening (0.22 bees/ capitulum/ 5min for each) with an average of 0.25 bees/ capitulum/ 5min. for entire flowering period (Table 2).

In general the number of *A. cerana* foragers increased with increase in number of disc florets opening per capitulum. This also recorded two peak activity periods. During morning hours pollen foragers were comparatively more than nectar foragers and afternoon hours nectar foragers were more than pollen foragers. *A. cerana* pollen foragers visited most intensively during 11.00 to 12.00 hrs and nectar foragers were maximum during 16.00 to 17.00 hrs. More or less similar observations were reported by Roopa (2002) ^[9] under Bengaluru condition with respect to *T. iridipennis* where she reported two distinct peaks of pollen and nectar foraging between 12.00 to 13.00 hrs. and 13.00 to 14.00 hrs. respectively.

Table 2: Activity of pollen and nectar foragers of *Apis cerana* Fab. during different stages of disc florets opening

| Percent flower opening | Pollen | Nectar |
|------------------------|------------|------------|
| <25 percent | 0.88± 0.51 | 1.32± 0.76 |
| 26- 50 percent | 1.21± 0.59 | 1.66± 0.62 |
| 51- 75 percent | 1.68± 0.86 | 2.05± 1.05 |
| > 75percent | 1.91± 0.90 | 2.34± 1.09 |
| Mean | 1.42 | 1.84 |
| SD | 0.46 | 0.44 |
| CD @ 5% | 0.73 | 0.71 |

**Fig 2:** Activity of pollen and nectar foragers of *Apis cerana* Fab. during different stages of disc florets opening

Pollen carrying capacity of *A. cerana* in corbicula during peak time of activity on Sunflower

The mean pollen weight carried by *A. cerana* during peak foraging time (11.00-12.00 hrs) on sunflower was 9.7 mg (n=10) which ranged from 5.6 mg to 13.8 mg (Table 3). The mean body weight of *A. cerana* was 43 mg with a minimum body weight of 37.9 mg and a maximum body weight of 49.5 mg. The mean ratio of bee body weight and pollen weight is 4.41. In general, the pollen-carrying capacity increased with increase in body weight.

The average body weight of *A. cerana* was 54 mg with the body weight ranging from 38 mg to 75 mg (Thripurasundari *et al.*, 2017). Similarly in the current study an average body

weight of *A. cerana* was 43 mg with body weight ranging from 37.9 mg to 49.5 mg.

Noritia *et al.*, 2017 reported The average body weight of *Tetragonula laeviceps* was 2.67 mg ± 1.01 (n = 6), *L. terminate* was 5.00 mg ± 0.53 (n = 6), and *Heterotrigona itama* was 10.55 mg ± 5.5 (n = 4). The average pollen load on each species of stingless bees varied. The highest pollen loads were observed in *H. itama* (31392 pollen grains), followed by *L. terminata* (23017 pollen grains), and *T. laeviceps* (8015 pollen grains). Pollens attached on the body was positively correlated with body weight ($y = 3854.2x + 3492.2$, $R^2 = 0.2654$, $p = 0.017$).

Table 3: Pollen carrying capacity of *A. cerana* in corbicula during peak time of activity on Sunflower

| Bee no. | Body wt.(mg) | wt. of pollen load (mg) | Ratio of body wt. and pollen wt. |
|---------|--------------|-------------------------|----------------------------------|
| 1 | 49.5 | 13.8 | 3.59 |
| 2 | 37.9 | 9.5 | 3.99 |
| 3 | 41.7 | 11.4 | 3.66 |
| 4 | 46.2 | 12.3 | 3.76 |
| 5 | 44.1 | 5.6 | 7.88 |
| 6 | 39.2 | 8.2 | 4.78 |
| 7 | 47.1 | 9.3 | 5.06 |
| 8 | 42.6 | 10.4 | 4.10 |
| 9 | 44.5 | 9.7 | 4.59 |
| 10 | 37.6 | 7.5 | 5.01 |
| Mean | 43.0 | 9.7 | 4.41 |
| SD | 4.0 | 2.3 | 1.68 |
| CD @ 5% | 2.8 | 1.7 | 0.90 |

Quantitative parameters of sunflower

The visual observations on open pollinated sunflower recorded 5.75% of unfilled seeds in capitulum near center, significantly highest seed setting, higher per cent of filled seeds followed by *A. cerana* and the least was recorded in case of sunflower enclosed to avoid pollination (Table 4).

Significantly maximum capitulum weight, higher test weight and higher yield per hectare was recorded with both open pollinated sunflower and the sunflower enclosed with *A. cerana*. There was an increase in the seed yield to the extent of 68 percent over control due to pollination by bees.

The similar results were recorded in case of KBSH-53 (Annon, 2016-17); Significantly highest seed yield of sunflower with honey bee colonies at Dharwar was recorded by Shivanagouda, (2013) [10]; Similar observations were made by Roopa (2002) [9] reported highest test weight in stingless bee enclosed crop (61.50 g/head) followed by open pollination (61.00 g/head) and control (55.50 g/head). These significant differences were similar with current studies but the variation in weight is due to different varieties used (Morden seeds are usually bolder than KBSH 44).

Qualitative parameters of sunflower:

There was no significant difference in oil percent between treatments. Similar observations were reported by Annon. (2014- 15) on sunflower hybrid KBSH-44. No significant difference between oil percent was observed among open pollinated sunflower (31.88%), sunflower enclosed with *A. cerana* (33.09%) and sunflower enclosed to avoid pollinators (30.41%). Open pollinated sunflower (44.93g/ 100ml) and sunflower enclosed with *A. cerana* (43.81g/ 100ml) recorded higher volume weight when compare from sunflower enclosed to avoid pollinators (41.74g/ 100ml). The results obtained in present studies are in accordance with other workers who carried out similar studies. The highest volume weight of sunflower hybrid KBSH- 44 was recorded in Sunflower enclosed with *A. cerana* (50.7g/ 100ml) followed by open pollinated sunflower (46.4g/ 100ml) and sunflower enclosed to avoid pollinators (32.1g/ 100ml) (Annon, 2016-17). Open pollinated sunflower recorded significantly higher

seed index (100 seed weight) (5.82g) which was on par with sunflower enclosed with *A. cerana* (5.62g) and the lowest was reported from sunflower enclosed to avoid pollinators (5.27g). Annon, (2016-17) reported highest 100 seed weight in open pollinated (5.7g) sunflower hybrid DRSH- 1 followed by sunflower enclosed with *A. cerana* colony (5 g) and sunflower enclosed to avoid pollinators (3.4g). Pollinator contributes more towards increasing 100 seed weight (seed index). Significantly highest kernel weight was recorded in open pollinated sunflower seeds (4.36g) which was on par with with *A. cerana* treatments (4.11g). The lowest kernel weight was recorded in sunflower enclosed to avoid pollinators (3.77g). Sunflower enclosed with *A. cerana* was recorded significantly maximum kernel husk ratio which was on par with open pollinated sunflower and minimum kernel husk ratio was recorded in sunflower enclosed to avoid pollinators (2.56). Total germinated seeds were significantly highest in open pollinated sunflower (48.33) which was on par with sunflower enclosed with *A. cerana* (46.33). The lowest germinated seeds were recorded in sunflower enclosed to control pollinators (38.66). Germination percent was statistically highest in open pollinated sunflower (96.67%) which was on par with sunflower enclosed with *A. cerana* (92.66%). The lowest germination percent was recorded from sunflower enclosed to control pollinators (77.33%). The shoot length was significantly highest in open pollinated sunflower (15.47cm) which was on par with sunflower enclosed with *A. cerana* (14.86cm). The lowest shoot length was recorded in sunflower enclosed to control pollinators (13.8cm). Significantly maximum root length was recorded in open pollinated sunflower (25.47cm) and was on par with sunflower enclosed with with *A. cerana* (24.63cm) and least root length was recorded from sunflower enclosed to avoid pollinators (23.83cm). Significantly highest seedling vigour was recorded in open pollinated sunflower (1520) which was on par with sunflower enclosed with with *A. cerana* (1402). The lowest vigour was from sunflower enclosed to avoid pollinators (1090). Vigour index value increases with increase in quality of seeds.

Table 4: Quantitative parameters of sunflower under different treatments

| Treatment | Total seeds | Total filled seeds | Percent filled seeds | Wt. of seeds per Head (g) | Yield/ha(kg) | Test wt.(g)* |
|-----------|---------------|--------------------|----------------------|---------------------------|---------------|--------------|
| T1 | 1163.4± 259.2 | 1036.6± 189.7 | 89.1± 4.89 | 48.4± 2.1 | 2686.9± 158.3 | 45.2± 2.9 |
| T2 | 1132.5± 342.7 | 814.2± 287.6 | 71.9± 8.26 | 44.7± 4.3 | 2484.8± 178.7 | 41.8± 3.6 |
| T3 | 1194.0± 302.5 | 1125.3± 147.3 | 94.3± 3.25 | 48.0± 1.8 | 2669.1± 124.5 | 44.9± 1.6 |

*1000 seed weight

T1: Sunflower enclosed with *A. cerana* colony

T2: Sunflower enclosed to avoid pollinators

T3: Open pollinated sunflower

Table 5: Qualitative parameters of sunflower under different treatments

| Treatment | Seed index (g)** | Kernel wt.(g) | Kernel husk ratio | Volume wt. (g) | Oil percent | Germinated seeds | Percent germination | Shoot length (cm) | Root length (cm) | Vigour index | Germinated seeds |
|-----------|------------------|---------------|-------------------|----------------|-------------|------------------|---------------------|-------------------|------------------|--------------|------------------|
| T1 | 5.62± 0.24 | 4.11± 0.17 | 2.74± 0.34 | 43.81± 2.61 | 32.58 | 46.33± 1.15 | 92.66± 2.31 | 14.86± 1.35 | 24.63± 0.40 | 1402 | 46.33± 1.15 |
| T2 | 5.27± 0.19 | 3.77± 0.13 | 2.56± 0.38 | 41.74± 1.78 | 32.96 | 38.66± 2.51 | 77.33± 5.03 | 13.8± 0.30 | 23.83± 0.25 | 1090 | 38.66± 2.51 |
| T3 | 5.82± 0.23 | 4.36± 0.11 | 3.01± 0.29 | 44.93± 2.41 | 33.06 | 48.33± 0.58 | 96.67± 1.15 | 15.47± 1.15 | 25.47± 0.15 | 1520 | 48.33± 0.58 |

**100 seed weight

T1: Sunflower enclosed with *A. cerana* colony

T2: Sunflower enclosed to avoid pollinators

T3: Open pollinated sunflower

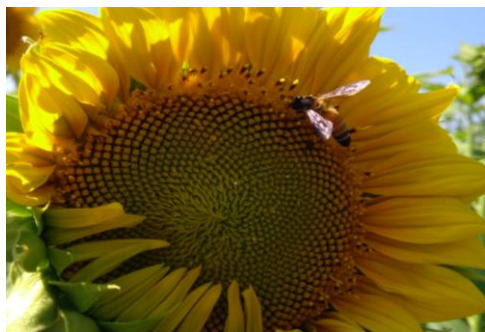


Plate 1: <25 percent of disc florets opened

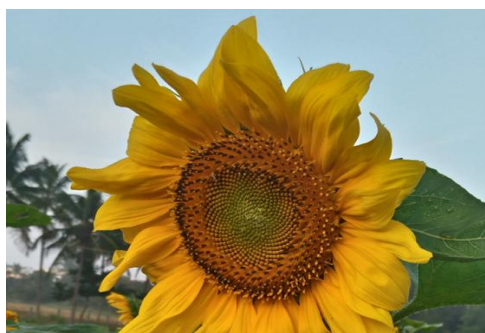


Plate 2: 26- 50 percent of disc florets opened

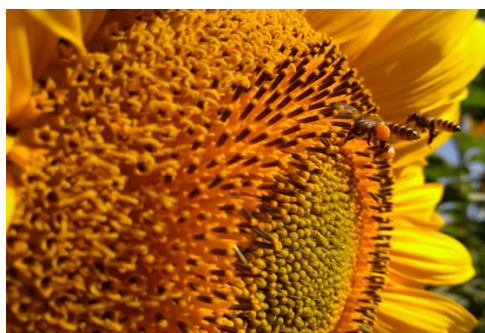


Plate 3: 51- 75 percent of disc florets opened



Plate 4: >75 percent of disc florets opened



Plate 5: Sunflower enclosed with *A. cerana* colony



Plate 6: Sunflower enclosed for avoiding pollinators



Plate 7: Open pollinated sunflower

Summary

Field investigations were carried out at the Zonal Agricultural Research Station, GKVK, Bengaluru during kharif 2017 by using KBSH-44 sunflower hybrid. The diversity and abundance of pollinators in sunflower was recorded during the flowering period. Foraging pattern of the different pollinators was recorded from morning 6.00 to 18.00 hours during the complete flowering period. The ratio of body weight to pollen load was calculated during peak foraging period. The quantitative and qualitative parameters were recorded for different treatments.

Observations were recorded with respect to percent of disc florets opening in flower i.e., (<25% (2nd day), 26-50% (4th day), 51-75% (6th day) and >76% (8th day) flower opening). The mean number of *A. cerana* pollen foragers was 1.42 bees/ capitula/ 5 min. for entire flowering period. The mean number of *A. cerana* nectar foragers was 1.84 bees/ capitula/ 5 min for entire flowering period. The mean ratio of *A. cerana* body weight and pollen weight was 4.41. In general, the pollen-carrying capacity increased with increase in body weight.

Conclusion

A. cerana are one of the good pollinators among different *Apis* and Non-*Apis*. They are handy, easy to maintain, and colony size is smaller which helps the beekeeper to manage easily for better yield. Overall, these bees helps in increasing sunflower yield when compare to the sunflower enclosed to control pollinators. Henceforth, *A. cerana* can be recommended for the sunflower pollination for better yield.

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