IMPACT OF HONEYBEE POLLINATION ON QUALITATIVE AND QUANTITATIVE PARAMETERS OF CUCUMBER (*Cucumis sativa* L.)

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I. INTRODUCTION

Honeybees are social insects with which man has established a harmonious co-existence. They are of great importance because, they not only produce honey and wax, but also pollinate many crops and trees. It is due to bee pollination that the crop yield increases and improves in quality and quantity of seed and fruit yield. Therefore, bee keeping can play a vital role in improving crop yields besides resulting in to an additional source of income through honey and bee-wax.

Utilization of pollinators especially honeybees is considered as one of the cheapest and ecofriendly approach in maximizing the yield of cross pollinated crops (Free, 1970). Many investigations have consistently confirmed that yield levels can be increased to an extent of 50 to 60 per cent in fruits and plantation crops, 45 to 50 per cent in sunflower, sesamum and niger and 100 to 150 per cent in cucurbitaceous crops, through good management of pollinators (Melnichenko and Khalifman, 1960). Insect pollination of crops is an essential crop management practice and should be utilized skilfully by harnessing the activity of domestic honeybees, wild bees and other pollinators including solitary bees. Achievement of desired pollination lies in the planned and efficient use of honey bees to increase the yield as well as improving qualitative and quantitative parameters of the crop.

Cucurbits form an important and vast group of vegetable crops cultivated extensively in India. The cucurbitaceae family comprises of many species of vines with creeping growth habit *viz.* watermelon, pumpkin, cucumber, muskmelon, chow-chow, coccinia, bittergourd, ridgegourd, ashgourd, *etc*. which are either used as salad or for cooking or picking.

Flowering phenology of cucurbits ensures better cross-pollination for higher fruit set and yield. The flowers of cucurbits are usually manoceious as they produce male and female flowers separately on the same plant at different internodes. The flowering ratio of male to female is 15:1. The pistillate and staminate flowers open on the same day. But, the male flowers are borne first, a fortnight earlier than the female flowers. Both type flowers arise singly from different internodes. Insects are required for pollen transfer because of the large sized pollen grain, their stickyness and the way they are released from the anthers (Lauria and Fred, 1995). The female flower borne on ovary *i.e*., inferior ovary and the stigma is receptive throughout the day. In male flowers, anthers dehisces when the corolla expands but the pollens remains on the anther as a sticky mass. The maximum pollination occur in the forenoon. As the female flower closes in the afternoon and never reopens whether or not pollination has taken place further. The highest per cent of fruit set resulted from deposition of pollen on the stigma between 0900 to 1200 h of the day (Bailey, 1949).

Cucurbits are popular because they are easy to grow, doesn't require high inputs and can be grown even in soils of marginal fertility. They are useful to prevent soil erosion.

Cucumber (*Cucumis sativa* L.) a native to Northern India, constitutes an important green vegetables among the cucurbitaceous crops and is fourth most important vegetable after tomato, brinjal and onion. It is an ideal summer vegetable crop, cheaply grown for edible tender fruits preferred as a salad ingredient, pickles and as a cooked vegetable. Fruits vary in shape, size and colour which contain 0.40 per cent protein, 2.50 per cent carbohydrates, 1.50 mg iron and 2.00 mg of vitamin C in 100 g of weight. Fruits are good for people suffering from constipation, jaundice and indigestion.

In Karnataka, cucumber is grown over an area of 8009 hectares with the annual production of 1,14,122 tones and productivity of 14 tones/ha (Anon., 2005). Cucumber is highly cross pollinated crop and mainly depends on various agents including insects for its pollination as reproductive organs of male and female flowers occur separately on staminate and pistilate flowers. Pollen grains being sticky and large in size needs an agent to be transfer to the pistillate flowers for fruit set. Among the agents, the insects especially honey bees are known to be the most efficient pollinating agents of cucumber from many years (McGregor, 1976; Grewal and Sidhu, 1979). A minimum of 8 to10 visits by the bees is necessary for satisfactory fruit set (Conner, 1969).

Any material to increase visit of honeybee to specific crop could be of great practical value to harness the benefits of cross pollination. Commercial bee attractants *viz*., beeline, beehere, beescent, beescent plus, fruit boost and bee-Q are being used to boost the yield of pear, peach, blue berries, watermelon and apple in United States, Spain and Canada. However, in India studies on the use of bee attractants are meagre, though some studies have been made on pollination of cucumber, but no attempts have been made for exploring the possible use of bee attractants to boost the productivity in India.

The impact of bee pollination during blooming of the cucumber and use of different bee attractants for fruit and seed production has not been well understood as less work has been done in this regard. To fulfil this lacuna, the present investigation on pollination potentiality of honeybees on yield of cucumber was undertaken with the following objectives.

Objectives

1. To study the pollinator fauna of cucumber
2. To study the foraging behaviour of bees in cucumber
3. To study effectiveness of different bee attractants in attracting the bees in cucumber
4. To know Influence of bee pollination on qualitative and quantitative parameters of cucumber

II. REVIEW OF LITERATURE

The review of literature pertaining to pollinator fauna of cucumber, foraging behaviour of bees, effectiveness of different bee attractants in attracting the bees in and effect of bee pollination on qualitative and quantitative parameters of cucumber are presented here under. The literature on above aspects of cucumber is scanty, found hence, some related literature is also being presented.

2.1 POLLINATOR FAUNA OF CUCUMBER

In United States of America, it has been known that species of the genera *Peponapis* and *Xenoglossa* (Anthophoridae:Eucerinae) obtain their pollen solely from the indigenous and cultivated cucurbit flowers, although they may obtain nectar from several other sources. They are called "Sqash bee", because of their close association with squash, pumpkin and gourd (Linsley *et al*., 1955).

Alex (1957) reported that honey bees are the most important sharers of cucumber flowers and only few solitary bees of the species *Melissodes communis* seemed to be effective pollinators.

Bhambura (1958) opined that *Apis florea* Fab and *Melipona* sp. are the most working bees in cucumber fields near Bombay, but not the *Apis cerana* Fab.

Mathewson (1965) reported that the native East American bee, *P. prinosa* visit exclusively squash and pumpkin flowers. However, main pollinating insects of squash were honeybees and *Trigona rufiorus* (Latreille) in Sao Paulo State, Brazil (Amaral and Mitidieri, 1966), whereas, the principal pollinators of pumpkin under field conditions in Illinois (USA) were European honeybees (*Apis mellifera* Fab), squash bees, *Bombus* sp. and *Melissodes bimaculata*, in addition to the presence of *Diabrotica* sp. and *Acalymma* sp. (Jaycox *et al*., 1975).

Batra (1967) reported that *Apis florea* Fab. Visits more in number to flowers of *cucurbita maxima* L. as against *A. dorsata* Fab. and *Lasioglossum cattulum* Vachal and *L. massuricum* Bluth, *Nomia oxybeloides* Smith, *Nomioides minutissima* Rossi, *N. variegate* Oliver and *N. divisa* Cameron and were in negligible numbers.

Several species of solitary bees were found visiting watermelon flowers, but honey bees are reported as the principal pollinators (Goff, 1937; Brett and Sulivan, 1972).

Seyman *et al.* (1969) reported that the honey bees are extremely important for the pollination of cucumber crop. Atwal (1970) recorded more than 23 species of bees visiting cucurbitaceous flowers at Ludhiana. Of the various bees, *Apis dorsata* was the most abundant species visiting the flowers followed by *A. florea, Ceratina binghami* Cockerel, *Xylocopa pubescens* Spinola*, Nomioides* sp. and halictine bees.

Brewer (1974a) opined that honey bees were the adequate pollinators of watermelon in USA. Kapil and Chaudhury (1974) reported that of the total bee population, *A. florea* Fab. (33.1%), *Nomia* spp. (21.3%), *Halictus* spp. (19.3%), *Pithitis* sp. (11.3%), *Nomioides* sp. (8.3%) and *Xylocopa* sp. (6.0%) foraged on cucurbit flowers from June to September.

Apis spp. especially, *A. dorsata and A. florea* constituted 77.20 and 70.70 per cent of the total number of bees collected from *Cucurbita pepo* L. in 1974 and 1975, respectively at Ludhiana (Grewal and Sidhu, 1979).

Girish (1981) reported that *Apis* spp. were the most important resource partitioners of summer squash *viz., A. cerana, A. dorsata* and *A. florea,* which contributed 87, 10 and 3 per cent, respectively around Bangalore.

Mohan Rao and Suryanarayana (1988) observed the insects visiting watermelon and recorded honey bees, solitary bees and few dipterans. Of the honey bee species, *A. cerana*

(87%) was the principal resource partitioner at Vijayarai and was found to be more efficient pollinator than *A. florea* and *T. iridipennis*.

Cervancia and Bergonia (1990) reported that *Xylocopa chlorine*, *X. philippinesis*, *Megachile atrata* and *Apis dorsata* Fab. were the frequent visitors of pickling cucumber flowers in Philippines.

Shrivastava (1990) made observations on pollination of bottlegourd (*Lagenaria siceraria* Mol.) standl.), ridgegourd (*Luffa acutangula* Roxb.), wild bittergourd (*Momordica diocia* L.) and wild pointed gourd (*Trichosanthes cucumerina* Roxb.) and found that they were pollinated by the bug, *Cyrtopeltis tenuis*, sphingid moths, pyralid moths and the ladybird beetle, *Epilachana punctata*.

Shrivastava and shrivastava (1991) studied 23 species of insects visiting cucurbitaceous crop in Rewa (India), whereas, white flower gourd/bottle gourd (*Lagenaria ciceraria* (Mol.) Standl.) was visited by *Xylocopa fenestrate* Fab. for pollen and nectar and acted as a good pollinator (Sihag, 1990; Sihag, 1993).

Honey bees (*A. mellifera*) constituted 82.60 per cent of visitor to cucumber flowers (Nogueira-Coutao and Calmona, 1993).

Bernard *et al*. (1996) opined that honey bees, *A. mellifera* with an average of 54 per cent was the predominant pollinator of cantaloupe, followed by muscid flies.

Eswarappa (2001) reported that chow-chow crop was visited by 26 insect species, of which 14 belonged to Hymenoptera and four each to Diptera, Lepidoptera and Coleoptera. *A. dorsata, A. cerana, A. florea* and *T. iridipennis* comprised more than 82 per cent of the total insect pollinators of crop.

Cucumber crop was visited by 27 insect species, of which 16 belonging to Hymenoptera and four each to Diptera, Lepidoptera and Coleoptera. The hymenopterans *viz.*, *A. dorsata, A. cerana, A. florea* and *T. iridipennis* comprised more than 82 per cent of the total insect pollinators (Prakash, 2002).

Nidagundi (2004) reported that among the 10 species of pollinators in bittergourd, *Apis florea* F. was the most predominant constituting 43.00 per cent of the total pollinators, followed by *A. cerana* (26.00%), *A. dorsata* (13.00%) and other pollinators (18.00%).

2.2 FORAGING BEHAVIOUR OF BEES IN CUCUMBER

Durham (1928) reported that *Diabrotica trivittata* (Mann) was a strong competitor of bees in the pollination of *C. pepo* L. and more pollen clinged to the insect. He also reported that bees carried large number of pollen grains between 0830 and 0930 h and least pollen grains per bee was at 1530 h.

Many workers reported the bee activity on the cantaloupe flowers shortly after it opens (0700 to 0800 h) and reached peak at about 1100 to 1200 h and then becomes scanty in late afternoon (McGregor, 1950; McGregor and Todd, 1952; Mann, 1953; McGregor *et al*., 1965).

Bhambura (1958) recorded that *A. cerana* Fab., *A. florea* Fab. and *Melipona* sp. started collection of pollen from watermelon at 0830 h and thier activity reached the peak at 1030 h. *A. cerana* Fab deserted the crop every day by 1200 h, but *A. florea* Fab. continued to work till sunset in Bombay.

Sanduleac (1959) in Rumania observed that honey bees work on the cucurbit flowers (*C. pepo* L., *C. maxima* D. and *C. moschata* Duch ex Poir.) most intensively from 0600 to 1200 h with a maximum activity from 0800 to 0900 h. Honeybees worked on the staminate flowers more vigorously than the pistillate flowers.

Shemetkov (1960) from Russia and Amaral and Mitidiery (1966) from Brazil reported that bees collect cucumber pollen heavily from 0800 to 1000 h and nectar from 1000 to 1200 h of the day.

Shemetkov (1960) from Russia and Nemirovich-Danchenko (1964) from Siberia reported that bees collected nectar from cucumber flower between 1000 and 1200 h. Both pistillate and staminate flowers of cucumber produced nectar and were attractive to honeybees (Conner, 1969).

Conner-Michigan (1969) reported that the best time of the day for effective cucumber pollination was from 1000 h to 1500 h. A cucumber flower needs at least 8 to 10 bee visits for satisfactory fruit set.

Seyman *et al.* (1969) opined that the honey bees are extremely important for the pollination of cucumber crop and the major portion of bees pollination activity occurs during the mid day period.

Kauffeld and Williams (1972) in Wisconsin reported that the honeybees collected nectar throughout the day from cucumber flowers with peak activity during 1100 to 1430 h.

Italian honeybee, *A. mellifera* collected nectar from both staminate and pistillate flowers of cucumber and has spent more time on pistillate flowers compared to staminate flowers. Majority of bee visits (80.0%) was between 0900 and 1400 h with a preference to pistillate flowers before 0900 h, followed by staminate flowers. On an average, each visit and time spent on pistillate flowers was twice the time as that of staminate flower and the overall foraging rate was 5.30 bees/flower/minute (Collison, 1973 and 1976).

Girish (1981) observed that during February *A. cerana* began foraging on summer squash at 0620 h, whereas *A. dorsata* and *A. Florea* at about 2 hr later and all species ceased foraging at about 1200 h.

Rapp (1981) recorded that honeybees started foraging on cucumber flowers at about 0600 h and their activity was maximum from 0900 to 1200 h and found decreased in the afternoon hours.

Fakuda (1987) reported that honeybee activity on watermelon flower was highest from 0800 to 1000 h and the bees visited male flowers more frequently than female flowers.

Mohana Rao and Suryanarayana (1988) stated that *A. carena* was the principal pollinating insect and was found to be efficient pollinator than *A. florea* and *T. iridipennis*. Further, *A. florea* activity was maximum at 0900 hr as the pollen gatherers were maximum during this period. And also recorded that during pollen collection in watermelon, *A. cerana* Fab spent 1.40 to 6.90 seconds on each staminate flowers. They spent less time in the early hours and the time spent was steadily increased upto 1100 h during which time pollen availability was decreased.

Cervancia and Bergonia (1990) reported that common flower visitors of cucumber were *A. dorsata* F, *Xylocopa chlorinae*, *X. philippiinensis* Smith, *Megachile atrata* Smith and were most abundant from 1000 h to 1100 h.

Sattigi *et al.* (1996) reported that in general foraging activity of honey bees was noticed throughout the day, but it was at its peak between 0800 to 1100 h in winter, 0600 to 1100 h and 1600 to 1800 h in summer and 0800 to 1200 h in monsoon irrespective of the crops in transitional area. The foraging activity was low during other hours of the day in different seasons.

Eswarappa (2001) reported that the activity of different species of honeybees either in open plots or caged plots of chow-chow was found to be mximum at 1000 to 1100 h and lowest at 0600 h. Same author reported that the peak pollen foraging activity was found at 1000 h and the time spent by different honeybee species for collection of pollen was found to

be maximum between 0800 and 0900 h in chow-chow. Among the honeybees, maximum time spent in collection of pollen was by *A. florea* (14.63 sec.), followed by *T. iridipennis* (12.89 sec), *A. cerana* (7.59 sec), *A. mellifera* (6.77 sec.) and the lowest in *A. dorsata* Fab. (5.77 sec.).

Prakash (2002) reported that the peak nectar foraging activity of honeybees was found at 1300 h of the day. Also, the time spent by different honeybee species in collection of nectar from pistillate and staminate flowers was found to be maximum at 1300 h in cucumber. The time spent by *A. florea* in collection of nectar from both the sexes was found to be maximum (305.93 sec. on pistillate and 276.68 sec on staminate flower), followed by *T. iridipennis* (9286.61 sec on pistillate and 271.99 sec on staminate flower), *A. mellifera* (37.47 sec on pistillate and 34.00 sec on staminate flower) and *A. cerana* (38.12 sec on pistillate and 35.31 sec on staminate flower). The lowest time spent was recorded in *A. dorsata* (3.52 sec on pistillate and 31.44 sec on staminate flower).

Prakash (2002) reported that the activity of *A. cerana* either in open plots or caged plots of cucumber was found to be maximum at 1000 h and lowest at 1800 h. Further,he reported that the peak pollen foraging activity of *A. cerana* was found at 1000 hr and also the time spent by different honeybees species in collection of pollen was found to be maximum between 0800 and 0900 h in cucumber. Among the honeybees, maximum time spent in collection of pollen was found in *A. florea* (13.49 sec), followed by *T. iridipennis* (11.44 sec.), *A. cerana* (9.65 sec), *A. mellifera* (8.74 sec.) and the lowest in *A. dorsata* (7.22 sec.).

Nidagundhi (2004) studied that foraging period of different bee species in which peak activity of *A. florea* was observed at 1200 h, *A. cereana* and others were active at 1000 h, while *A. dorsata* at 1200 h.

2.3 EFFECTIVENESS OF DIFFERENT BEE ATTRACTSNTS IN ATTRACTING THE BEES IN CUCUMBER

Woodrow *et al.* (1965) screened the natural and synthetic materials as attractants and repellents for *A. mellifera* by observing responses of bees to their vapours. Out of 195 formulations tested, four were rated as weak to moderate attractants and 19 were moderate to very strong repellents *viz.,* alcohols and one fatty acid having more carbon atoms.

Williams *et al.* (1981) reported that nasonov pheromone of honey bee comprised of seven components and among these, the presence of 'foot print pheromone' enhanced the attractiveness of synthetic nasonov pheromone. They opined that this could prove useful in attracting the honey bees to the crops for better pollination.

Field trials were conducted on two adjacent fields of *Citrullus lanatus* L. in Arizona, USA, in which honey bees were introduced at a stocking density of two colonies/acre. Bee scent was sprayed over alternate 18 row strips in one field and the other field was untreated. Though, bee visitation was high on the day of application, but did not reflect in yield (Looper and Rossette, 1991).

Allsopp and Cherry (1991) studied the attraction of *A. mellifera* to volatile compounds and they concluded that anetholes and commercial trace janapese beetle lure (10:22:11, 2 phenyl ethyl propionate:eugenol:geraniol) exposed in trace in Japanese beetle traps attracted *A. mellifera,* but other floral lures and fattyacids did not attract the bees.

Two application of Bee scent (a liquid formulation containing 9.00 per cent phermone and 40.00 per cent other natural attractants) was used on watermelon cultivars in Florida. Total fruit yield was increased in one farm with the treatment upto 3000 fruits/acre compared to 1500 fruits/acre without treatment and there was apparent increase in early yield in three farms. The soluble solid contents of fruit was not affected by the treatment. The number of seeds per fruit was higher with treatment on three frames (Elmstrom and Maynard, 1991).

Henning *et al.* (1992) studied behavioural responses of *A. mellifera* to primary alfalfa floral volatiles in a screened flight chamber. They found that linalool was the only compound

attractive to honey bees at the optimised concentration. Two other compounds, 3-octanone and methyl salicylate were repellents. The remaining two compounds cis-3-hexenyl acetone and ocimine were neither attractive nor repellent.

The efficacy of Bee-here (Nasonov pheromone other honey bee attractant and control release formulation aids) as honey bee attractant to marrow crop (*Cucurbita pepo* L.) grown in greenhouse conditions in Almeria, Spain was tested. Honey bee counts were made on plants sprayed with recommended dose of attractant (3.00 ml/lit), plants sprayed with half the dose, plants sprayed with water and untreated plants. The bees did not exhibit preference for any experimental treatment indicating that this product being ineffective as a honey bee attractant to marrow flowers (Ortiz-Sanchoz, 1993).

Schultheis *et al.* (1994) evaluated two commercial bee attractants like Bee scent and Bee line on cucumber and watermelon. They found that these attractants did increase the yield and also bee visitation. Similarly, Ambrose *et al.* (1995) evaluated Bee line as honey bee feeding stimulant on watermelon and Bee scent as worker bee attractant on both cucumber and watermelon. They found that these attractants neither increased the bee activity on vine crop when compared to untreated control nor they increase the value of subsequent harvest.

According to Higo *et al.* (1995) a combination of increased recruitment of foragers and greater time spent by foragers with increased flower visitation contributed to the enhanced pollination of blooming crops treated with Fruit boost.

Viraktamath and Anagoudar (2002) reported that two applications of Bee-Q® (12.5 g/l), Bee-here® (4 ml/l) and sugar solution (10 %) on staminate flowers of *Cucumis sativa* enticed more number of bees (4.01 to 4.97 bees/flower.5 min.) up to 5 days after first and second sprays compared to unsprayed crop (3.25 to 3.59 bees). Similarly, higher visitation was recorded on pistillate flowers on the sprayed crop.

Lingappa *et al*. (1999) reported that increased 21.80 and 31.80 per cent in the number of fruits formed and total yield, respectively, when Bee-Q was sprayed twice on watermelon.

Application of Bee-Q @ 12.50 and 15.00 g/l resulted in higher yield (19.56 and 19.45 t/ha respectively), maximum good fruits, minimum malformed fruits and higher size and weight in watermelon (Sattigi *et al*., 2001a).

Dinesh (2003) reported that spraying of cacambe (10%), jaggery (10%) and Bee-Q (1.25%) had significantly influence in attracting more number of pollinators. Plots sprayed with cacambe (10%) recorded significantly more number of fruits (15.61 fruits/plant vs 7.42 and 3.34 without bees, respectively) and fruit weight (126.11 g/fruit).

Nidagundi (2004) reported that spraying of cacambe @ 10 per cent, Bee-Q @ 1.25 per cent and jaggery solution @ 10 per cent have significant influence in attracting more number of pollinations.

2.4 INFLUENCE OF BEE POLLINATION ON QUALITATIVE AND QUANTITATIVE PARAMETERS OF CUCUMBER

McGregor and Todd (1952) found that no melon flowers set fruit until the bees were introduced into caged melon plot, but when bees were introduced, there was a rapid fruit set resulting in the production of 184 marketable melons. But, the open melon plots produced only 145 melons as against four in plots caged without honey bees. Hence, it was opined that to get maximum quantity and better quality of melons, sufficient population of honey bees should be present throughout the flowering period (McGregor, 1950).

Mann (1953) found that 66.60 per cent of fruit set was obtained from bee pollination, whereas, only 38.70 per cent of cantaloupe fruit set was obtained by hand pollination. Brewer (1974b) reported the high correlation between melon weight, number of mature seeds (r=0.900) and weight of mature seeds (r=0.850), but contrary to very low correlation between melon weight and immature seeds. He also opined that more number of melons were

harvested from the plots visited by bees than from those where bees were excluded. However, high population of honey bees did not improve melon weight compared with normally occurring honey bee populations.

Taylor (1955) reported that the fields with and without honey bee colonies in the crop vicinity gave 1.10 and 0.70 melons per plant, respectively, which is equivalent to 230 and 160 crates/acre.

A number of workers claim to ensure cucumber pollination on yield parameters with eight visits per flower (Shemetkov, 1957; Mcgregor *et al*., 1965 and Conner, 1969), whereas less than eight bee visits produced less number of seeds (60) per fruit with lower fruit weight (22 kg), as compared to 140 seeds per fruit which weighted 500 g, when the flowers were visited 50 times (Shemetkov, 1957).

Adlerz (1960, 1961 and 1966) reported that the watermelon fruit set was significantly better after eight or more bee visits per flower and in the second year six or more bee visits per flower were significantly better than four or fewer bee visits per flower.

Verdieva and Ismailova (1960) found that 47 to 57 kg of squash yield was obtained from plots pollinated by honey bees compared with 25 to 30 kg from plots pollinated by other (Unspecified) methods. Battaglini (1969) in *C. pepo* recorded a fruit set of 61.20 per cent of the total pistillate flowers exposed to bees in comparison with fruit set of only 6.80 per cent, when flowers were caged.

McGregor *et al.* (1965) reported that the percentage of marketable melon increased with the number of bee visits. Ten bee visit per flower was enough and additional visits were not necessary.

Conner (1969) found that a single bee visit to pistillate flower often resulted in well shaped cucumber. At least ten bee visit was necessary to ensure pollination under all the conditions, whereas eight to twelve visits per blossom were needed to yield uniform sized cucumber (Stephen, 1970). On the contrary, Collison (1976) claimed that 15 to 20 bee visits were needed to get uniform cucumbers and multiple bee visits increased the average number of seeds, which resulted in better and maximum fruit weight.

Brewer (1974a) reported that honey bees were the adequate pollinators of watermelon in USA. Experiments in which pumpkin (*C. moschata* Duch ex Poir.) flowers were bagged to exclude bee visits and exposed to number of bee visits shown that the fruit set was 6.5 per cent after one visit and 64.5 per cent after 12 visits per flower. The pumpkin weight and number of seeds also increased with number of visits (Jaycox *et al*., 1975).

Among the different modes of pollination tried, Sunder (1978) obtained 326 watermelon fruits in bee pollination which was significantly superior to natural (272 fruits) or hand pollination (247 fruits). In case of bee pollination, about 28.00 per cent of fruits were carried to maturity as against 25.00 per cent in natural pollination and 23.00 per cent in hand pollination. Total fruit weight was maximum in bee-pollinated plants (738 kg) as against (671 kg) in natural and (456 kg) in hand pollinated flowers. Bold viable seeds were also more in bee pollination (66427) as compared to natural and hand pollinated flowers. In case of bee pollinated flowers, the percentage of bold viable seeds (46%) was more compared to the other two modes of pollination (about 27%). The dry weight of bold viable seeds was around 4 kg in natural and hand pollinated flowers compared to bee-pollinated flowers (7 kg).

Spangler and Moffett (1979) reported that fruit set ranges from 41 to 95 per cent of the total flowers visited by bees, whereas, no fruit was set in the plot without bees visit in melon.

Grewal and Sidhu (1979) obtained 60.46 to 64.30 per cent fruit set in open pollinated *C. pepo* plots as against 41.70 and 55.00 per cent fruit set, when 20 and 30 females of *Pithitis smaragdula* (solitary bee) were enclosed respectively in caged plots.

Wolfenbarger (1962) demonstrated the value of bees as pollinators in three ways; firstly, in all the three years he caged squash plants to exclude insects and found that the average yield was only 19 per cent; secondly, he found that the yield of fruit decreased with

distance from a group of 20 honey bee colonies put at one end of the field and thirdly, he found a positive correlation between the number of honey bee colonies per acre and the number of fruits obtained. He got 148 baskets of fruit in a field where no colonies were provided, 155 baskets in less than one colony per acre (1/2 colony), 161 baskets in one colony per acre, 168 baskets in two colonies per acre and 173 baskets of fruit in field provided with three honey bee colonies per acre.

The cucumber yield was increased by 39 per cent with one honey bee colony per acre as compared to fields without bees (Steinhauer, 1971). Conner and Martin (1969) obtained higher yields of better quality cucumbers by caging the plants to exclude bees for first 11 days after the appearance of first pistillate flowers. They also noted that the delayed exposure of plants to bees for six days was sufficient to get optimum yield.

Kauffeld and Williams (1972) and Kauffeld *et al.* (1975) reported that honey bee pollination has increased the average weight and quality of cucumbers both in open and plots caged with honey bees. The yields of muskmelon fruits were higher in plants pollinated by bees and plants in which bees were excluded set practically no fruits.

Kauffeld and Nelson (1982) reported that the yield of pickling cucumber was highest in the plots caged with *A. mellifera* than open plots and was lowest in control plots.

Alam and Quadir (1986) reported that plots pollinated with *A. cerana* had 15 per cent fruit set and that of hand pollinated plots had 8 per cent and isolated plots had only 3 to 5 per cent fruit set in bottle gourd.

Williams (1987) in Australia, obtained 20, 26 and 27 melons from the plots caged to exclude bees, caged with honey bees and not caged, with a mean fruit weight of 0.68, 1.11 and 1.10 kg each and total of 13.40, 28.50 and 29.40 kg fruit weight per plot, respectively. The presence of honey bees increased average rockmelon weight by 40 per cent and increased number of rockmelons by 25 per cent.

Mohan Rao and Suryanarayana (1988) reported that there was no fruit set in watermelon plots excluded from insect pollinators. The fruit number and weight were more in honey bee pollinated crop than open pollination.

Fisher and Pomeroy (1989) reported that pollination by Bumble bee, *Bombus terrestrus* L. yielded 90 per cent of the melons produced were export quality and weight.

Cervancia and Bergonia (1990) reported that the fruit set of cucumber in bee and open pollinated plants were 75 and 58 per cent, respectively and these were significantly higher than the non-pollinated plants (33 %). Bee and open pollination also yielded heavier and uniform fruits.

Two application of Bee scent (a liquid formulation containing 9.00 per cent pheromone and 40.00 per cent other natural attractants) to watermelon cultivars in Florida resulted in increase in one farm with the treatment upto 3000 fruits/acre compared to 1500 fruits/acre without treatment and there was apparent increase in early yield in three farms. The soluble solid contents of fruit was not influenced by the treatment. The number of seeds/fruit was higher with treatment on three farms (Elmstrom and Maynard, 1991).

Gaye *et al.* (1991) reported that individual fruit weight of muskmelon was greater from row cover treatments with bees than without and was highly correlated with total seed weight.

Maynard *et al.* (1992) applied Bee scent to watermelon cultivars "Sangria" in Monatee county in autumn by foliar spray @ 4.60 l/ha at early pistillate bloom stage and again at full pistillate bloom stage. Another attractant, Bee-here was applied in the spring at 2.30 l/ha at the early pistillate bloom and full pistillate bloom stage to cultivars "Fiesta" plants in Monatee county and to "Crimson sweet" and "Big crimson" plants in lake country. In cv. Big crimson, the early yield and average fruit weight for whole season was significantly higher for the treated plots than control plots (7.10 vs 3.80 t/ha and 10.60 vs 9.90 kg, respectively). But, no

significant effect of bee attractant on fruit weight, fruit number or yield were observed in any of the treatments.

Rafiq-Ahmad (1992) reported that greater fruit weight was obtained (2.69 kg/plant) in honey bee pollinated plants compared to self-pollinated plants (2.03 kg/plant) in cucumber.

Cervancia and Forbes (1993) placed honey bees colonies at varying densities (0.25, 0.50, 1.0 or 0 hives/2000 plants) in cages of pickling cucumber (*Cucumis sativus* Var. Cu. 6). Fruit set and number of filled seeds were significantly higher in plots with 0.5 colony per 2000 plants and over population caused competition for flower, thus reducing pollination efficiency.

Honey bees (*A. mellifera*) constituted 82.6 per cent of visitor to cucumber flowers. Further, plots netted with bees yielded more fruits per m^2 and heavier and higher quality fruits than other plots i.e. open pollination and crop caged without bees (Nogueira coutao and Calmona, 1993).

Best results were obtained from with bees (*A. mellifera*) in sealed polyethylene tunnels which yielded 0.97 kg export grade fruits/plants compared to sealed polyethylene tunnels open at one end which gave 0.56 kg/plant (Froissart *et al*., 1995). Honey bees (*A. mellifera*) under covered with bees *A. mellifera* yielded good fruit size and good number of seeds and commercial grade fruit than control plots (Bernard *et al*., 1996).

The total number of watermelon fruits per plot was maximum (25.53 fruits) in plots treated with Bee-Q @ 15.00 g/l, but lower number of fruits were evident in the plots with control and water spray (16.66 and 17.00 fruits per plot, respectively). The highest yield of 19.56 t/ha was recorded in plots where Bee-Q was sprayed @ 12.5 g/l, which was on par with 15.00 g/l, the lowest yield was obtained in control and water spray (8.14 and 9.00 t/ha, respectively) (Anonymous, 1999).

Lingappa *et al.* (1999) reported that an increase of 21.80 and 31.80 per cent in the number of fruits formed and total yield, respectively when Bee-Q was sprayed twice on watermelon. Whereas in safflower, the seed yield was significantly enhanced to the extent of 54.84 per cent over the control. Further, spraying of Bee-Q and Bee here on sesamum increased bee visitation and yield parameters significantly on sprayed crop upto 5^{th} day in Dharwad (Patil, 1999 and Patil *et al*., 2000).

Eswarappa (2001) reported that maximum fruit set was noticed in open pollinated plots (81%) in chow-chow and lowest in control plot (10.5%). Among the honey bee species, maximum fruit set was found in *A. florea* caged plots (78%) and the lowest was found in *T. iridipennis* caged plot (61%). Also, maximum fruit weight and fruit volume was found in open pollinated plots and lowest in control plots. Among the honey bee species, maximum fruit weight and fruit size was found in *A. cerana* caged plots and the lowest was found in *T. iridipennis* caged plots.

Application of Bee-Q @ 12.50 and 15.00 g/l resulted in higher yield (19.56 and 19.45 t/ha, respectively), maximum good fruits, minimum malformed fruits and higher size and weight in watermelon (Sattigi *et al*., 2001a).

William Rajasekhar (2001) studied the effect of the bee pollination on water melon. Significantly higher fruits per 30 m^2 were recorded in two colonies per plot (22.37), followed by one colony per plot (20.75) and lowest was recorded with no colony (18.37). Similar results were obtained with respect to mean fruit weight, fruit diameter, TSS per cent and yield.

Viraktamath and Anagoudar (2002) reported that maximum number of good fruits (121.60) in the cucumber crop that received two sprays of attractants, followed by the crop which received sugar solution twice, one spray of Bee-Q, Bee-here and sugar solution. In contrast, lowest number of malformed fruits were recorded in the treatments that received two sprays of attractants (12.75 fruits/plot) and was on par with the caged crop with bees (13.0 fruits). However, unsprayed crop produced significantly higher number of malformed fruits (35.5 fruits) when compared to all other treatments.

Dinesh (2003) reported that the open pollinated crop which received cacambe (10%) recorded significantly least number of dropped fruit per plant in cucumber (0.76 fruit/plant) and significantly higher yield (41.52 kg/plot as against 30.92 and 20.52 kg/plot in open pollination without spray and caged plot without bees, respectively). Thus, these was an increase in the yield of 34.28 and 101.84 per cent over open pollination without spray and caged plot without bees, respectively.

Nidagundi (2004) reported that significantly highest length of fruits in bittergourd 26.10 cm as against 13.93 and 13.60 cm fruit length in open pollinated and caged plot without bees, respectively, led to pulp ratio of 0.132 as against 0.09 and 0.07 in open pollinated and caged plot without bees, respectively, highest fruit weight 129.208 as against 72.09 and 62.44 in open pollinated and caged plot without bees, respectively and yield of 118.87 q as against 68.63 and 45.23 q in open pollinated and caged plots without bees, respectively.

III. MATERIAL AND METHODS

The present investigations were carried out in farmers field in Mangalagatti village near by University of Agricultural Sciences, Dharwad. Mangalagatti is located 10 kms from Dharwad, just interior to Pune-Bangalore (NH-4) road. Dharwad is located 15°26' North latitude, 75°07' East longitude and at an altitude of 731.80 meters above the mean sea level (MSL). This lies in the northern transitional zone, which receives an average annual rainfall of 751 mm distributed well over the season. The average temperature and relative humidity ranges from 11 to 37°C and 40 to 85 per cent, respectively.

3.1 POLLINATOR FAUNA OF CUCUMBER

The study was made on crop raised during *rabi*, 2004-05. The experimental plot was kept free from any spray during flowering period. Observations were made for different groups of pollinators visiting the cucumber field during flowering at 0800, 1000, 1200 and 1400 h for five minutes in each square meter area from five spot during peak flowering period. The data were later averaged timewise and groupwise to infer the pollinator fauna as well as the dominance of particular group. And weather data like temperature, humidity and rainfall were recorded to correlate with pollinators.

3.2 FORAGING BEHAVIOUR OF BEES IN CUCUMBER

The study was made during *rabi*, 2004-05 in the unsprayed plots of the crop raised for studying pollinator fauna.

The observations were made at two hourly interval from 0800 to 1800 h on number of bees visiting in each square meter area from five spot for five minutes at weekly interval. The observations were initiated at 10 per cent flowering and continued at weekly intervals for five weeks. The time spent by the different bee species on five flowers were also recorded. Then the data was averaged timewise and species wise to draw the conclusion about dominant group and peak foraging time.

3.3 EFFECTIVENESS OF DIFFERENT BEE ATTRACTANTS IN ATTRACTING THE BEES IN CUCUMBER

The experiment was laid out in Randomised Block Design (RBD) with seven treatments replicated thrice. The treatment details are as follows;

T_1 - Open pollination with Cacambe @ 10%
T_2 - Open pollination with Bee-Q @ 1.25 %
T_3 - Open pollination with Sugarcane juice @ 10%
T_4 - Open pollination with Sugar solution @ 10%
T_5 - Open pollination with Jaggery @ 10%
T_6 - Open pollination with Molasses @ 10%
T_7 - Open pollination without any spray

Crop was raised in a plot size of 5 x 5 m following package of practices with spacing of 100 x 90 cm. Later, all the treatments were imposed at 10 per cent flowering of the crop. The attractants were sprayed three times at weekly intervals starting from 10 per cent flowering. In each plot, one square meter area was randomly selected and number of species of pollinators visiting the flowers per five minute were recorded at 0800, 1000, 1200, 1400 and 1600 h. The observations were made a day before the spray and 1, 3 and 5 days after I^{st}, II^{nd} and III^{rd} spray. Mean of all the observations were pooled for different bee pollinators separately. The data were subjected to statistical analysis for inference.

Plate 1: Crop caged with bees

Plate 2: Crop caged without bees

Plate 3: Healthy fruits

Plate 4: Mal formed fruits

3.4 EFFECT OF BEE POLLINATION ON QUALITATIVE AND QUANTITATIVE PARAMETERS OF CUCUMBER

The experiment was laid out in RBD with nine treatments replicated thrice. The treatment details are as under.

T_1	-	Crop caged with bees
T_2	-	Crop caged without bees
T_3	-	Open pollination with Cacambe @ 10%
T_4	-	Open pollination with Bee-Q @ 1.25 %
T_5	-	Open pollination with Sugar solution @ 10%
T_6	-	Open pollination with Jaggery @ 10%
T_7	-	Open pollination with Molasses @ 10%
T_8		Open pollination with Sugarcane juice @ 10%
T_9	-	Open pollination without any spray

This study was made in *rabi* season of 2004-05 and experiment was laid out as under 3.3 with addition of two treatments (T_1 and T_2). T_1 and T_2 were caged before the start of flowering during night to eliminate natural pollinators. Later, all the treatments ($T_3 – T_8$) were imposed at 10 per cent flowering of the crop. Spraying was done three times at ten days intervals starting from 10 per cent flowering of the crop. Bee hive with back and front entrance was kept open in one boundary of cage to facilitate the bees to move in and out either inside or outside the cage. The cage was removed after completion of flowering.

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

Number of flowers per plant:

In each treatment five plants were selected randomly. The number of female flowers in these plants were counted and mean number of female flowers per plant was calculated.

Number of fruit in each plant:

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

Per cent fruit set:

The fruit set in all the treatments was estimated by counting the number of fruit set out of female flowers. The mean fruit set was expressed in per cent.

$$\text{Per cent fruit set} = \frac{\text{Number of fruits set}}{\text{Number of female flowers}} \text{ X } 100$$

Healthy and malformed fruits per plant:

In each treatment, five plants were selected randomly for the observation. Out of total number of fruits, healthy and malformed fruits per plant were counted and mean number of healthy and malformed fruits per plant was calculated.

Length of the fruits:

The observation was made by selecting fruits randomly from each treatment and length of fruits was measured using scale or measuring tape. The data was subjected to statistical analysis.

Diameter of the fruits:

The observation was made by selecting fruits randomly from each treatment and measured by using Vernier Caliperse. The data was subjected to statistical analysis.

Weight of each fruit:

The observation was made by selecting five plants at random from each treatment of all replications during harvesting. The average fruit weight was computed by taking total weight of all fruits.

Net plot yield:

The fruit harvested from each plot were weighed and recorded during each picking and noted the net plot yield at the end by excluding the one plant in each middle rows on either side.

Yield per ha (converted):

Net plot yield was later converted to one hectare area for each treatments. Later, the data on various quantitative parameters was subjected to statistical analysis.

IV. EXPERIMENTAL RESULTS

The results of the present investigations carried out on pollinator fauna, foraging activity of honey bees, effectiveness of different bee attractants in attracting the bees and effect of bee pollination on qualitative and quantitative parameters of cucumber yield conducted at Mangalagatti village, near to Main Agricultural Research Station, Dharwad are presented in this chapter.

4.1 POLLINATOR FAUNA OF CUCUMBER

As many as 12 species of pollinators (Table 1) were recorded during the present study, out of which 9 species belonged to Hymenoptera, 1 to Lepidoptera and 2 to Diptera. Among the total number of 304 pollinators visitation recorded to cucumber field *Apis florea* was the most predominant species constituting 42 per cent followed by *Apis cerana* (24%), *Apis dorsata* (14%) and others (20%).

4.2 FORAGING ACTIVITY OF DIFFERENT HONEY BEE SPECIES ON CUCUMBER

4.2.1 Foraging activity of rock bee, *A. dorsata* on cucumber

The foraging activity of *A. dorsata* on cucumber was observed from 0800 to 1800 h of the day during first week after 10 per cent flowering. Foraging activity commenced at 0800 h with 1.40 bees/m²/5 min. It gradually increased and attained the peak (5.90 bees/m²/5 min) at 1200 h. At 1000 and 1400 h almost same number of bees were recorded *i.e.* 3.25 and 3.00 bees/m²/5 min, respectively. Whereas, less activity of 2.10 and 1.60 bees/m²/5 min was recorded at 1600 and 1800 h of the day, respectively (Table 2).

During the second week, the bee activity commenced at 0800 h with 1.60 bees/m²/5 min and as the day advanced, bee activity increased and attained the peak (6.22 bees/m²/5 min) at 1200 h. The lowest bee activity was noticed at 1800 h with 2.10 bees/m²/5 min.

The foraging activity started at 0800 h with 1.50 bees/m²/5 min during third week after 10 per cent flowering and maximum activity was found 1200 h with 7.10 bees/m²/5 min. The lowest foraging activity was found to 1800 with 1.40 bees/m²/5 min.

During fourth week after 10 per cent flowering, the foraging activity started at 0800 h with 2.00 bees/m²/5 min. The maximum activity was found at 1000 to 1200 h of the day with 5.60 and 7.40 bees/m²/5 min, respectively. But least activity was found at 1800 h with 2.30 bees/m²/5 min.

Similar trend was observed during fifth week after 10 per cent flowering, where the peak foraging activity was observed at 1000 to 1200 h of the day with 4.70 and 7.00 bees/m²/5 min, respectively.

The comparative foraging activity of rock bee during different weeks after 10 per cent flowering indicated that the total number of rock bees that visited the cucumber plot during the flowering period were 102.97 bees/m²/5 min.

On an average *Apis dorsata* foraging activity was observed from 0800 to 1800 of the day, with highest foraging activity of 6.72 bees/m²/5 min at 1200 h which was followed by a next peak at 1000 h with 4.68 bees/m²/5 min. However, lowest bee activity was observed at 0800 and 1800 h of the day with 1.56 and 2.07 bees/m²/5 min, respectively (Table 2).

There was no significant difference in the mean bee foraging activity on cucumber flowers observed at weekly intervals with the range of 2.87 to 3.87 bees/m²/5 min.

Table 1. Pollinator fauna of cucumber

Sl. No.	Pollinator	Systematic position		Relative abundance of pollinators (%)
		Order	Family	
1.	*Apis dorsata* F.	Hymenoptera :	Apidae	14
2.	*Apis florea* F.	Hymenoptera :	Apidae	42
3.	*Apis cerana F.*	Hymenoptera :	Apidae	24
4.	*Nomia* spp.	Hymenoptera :	Halictidae	
5.	*Helictus* spp.	Hymenoptera :	Halictidae	
6.	*Trigona irridepennis*	Hymenoptera :	Miliponidae	
7.	*Megachile conata*	Hymenoptera :	Megachilidae	
8.	*Coelioxys* spp.	Hymenoptera :	Megachilidae	20
9.	*Xylocopidae* spp.	Hymenoptera :	Xylocopidae	
10.	*Eristalinus arvorum* (F)	Diptera :	Syrphidae	
11.	*Bombilidae* spp.	Diptera :	Bombilidae	
12.	*Ixias Marianne* (Cramer)	Lepidoptera :	Pieridae	

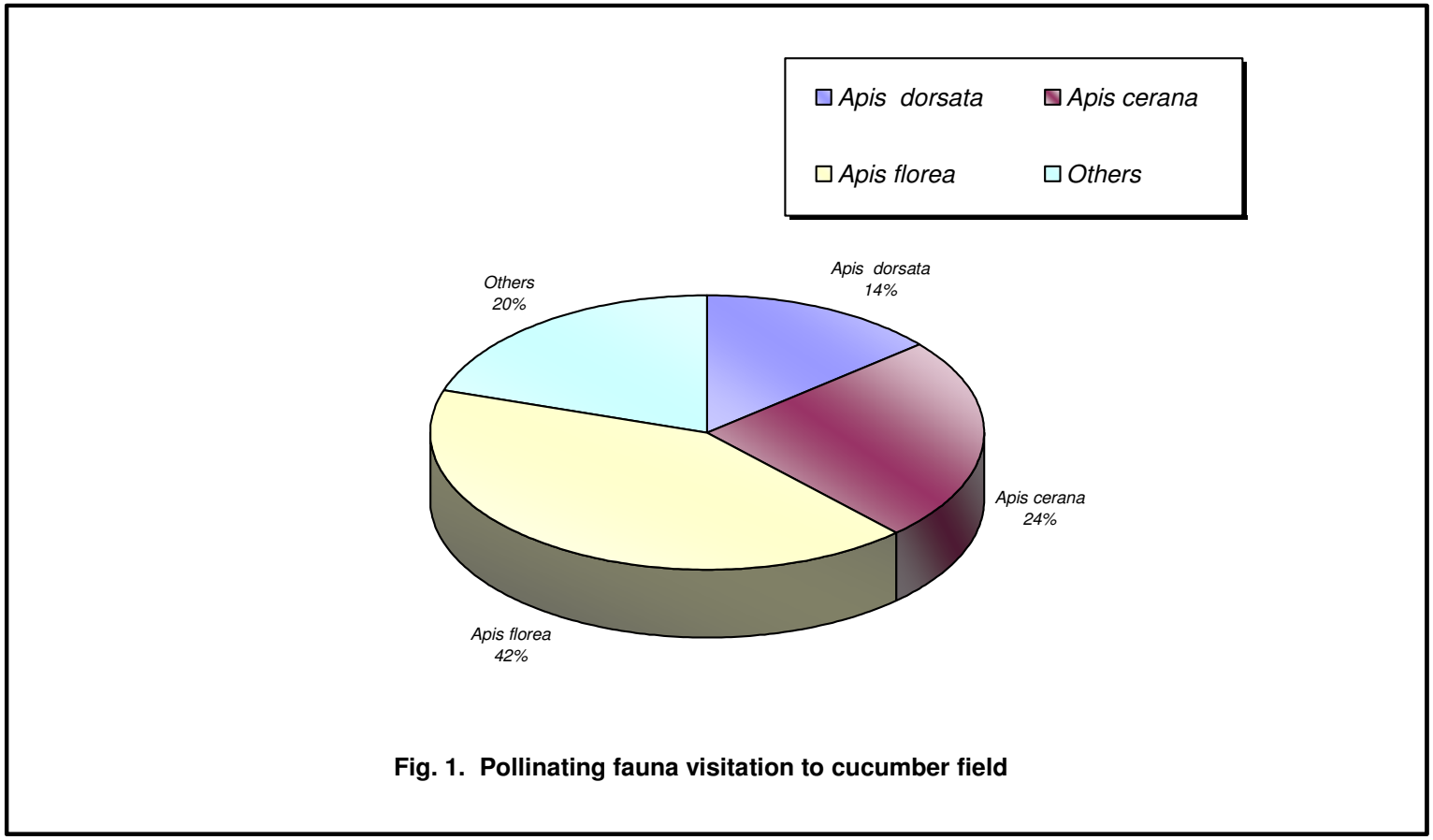

Fig. 1. Pollinating fauna visitation to cucumber field

Fig.1. Poollinating founa visitation to cucumber field

Apis cerana

Apis florea

Apis dorsata

Coelioxys sp.

Halictus sp.

Plate 5. Important pollinators on cucumber

Table 2. Foraging activity of *Apis dorsata* on cucumber

Time (hours)	Number of bees/m²/5 min						
	Ist week	IInd week	IIIrd week	IVth week	Vth week	Total	Mean
0800	1.40	1.60	1.50	2.00	1.30	7.80	1.56^{d}
1000	3.25	4.85	5.01	5.60	4.70	23.41	4.68^{b}
1200	5.90	6.22	7.10	7.40	7.00	33.62	6.72^{a}
1400	3.00	2.95	3.25	3.48	3.10	15.78	3.15^{c}
1600	2.10	2.45	2.80	2.48	2.20	12.03	2.41^{cd}
1800	1.60	2.10	2.18	2.30	2.15	10.33	2.07^{d}
Total	17.25	20.17	21.84	23.26	20.45	102.97	
Mean	2.87a	3.36a	3.64a	3.87a	3.40a		

Means followed by same alphabets do not differ significantly by DMRT at 0.05%

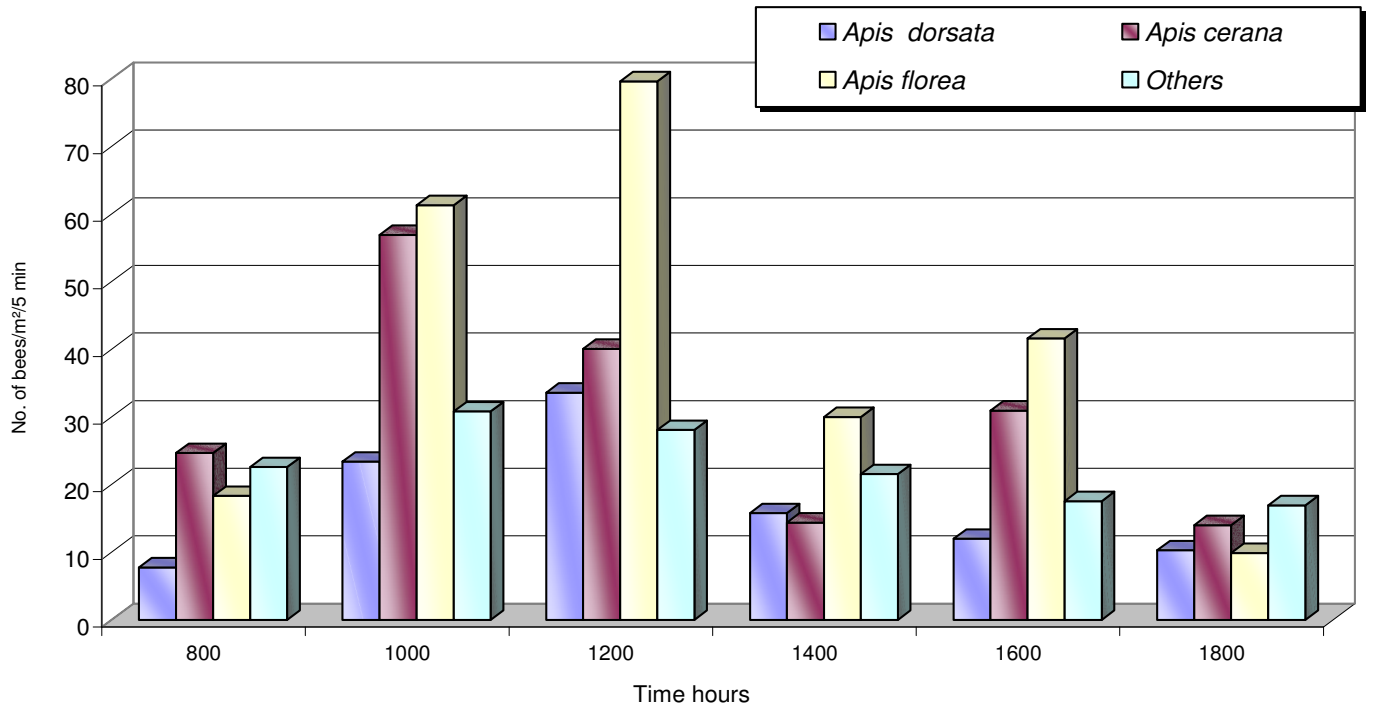

Fig. 2. Foraging activity of other pollinators on cucumber

Fig.2. Foragibg activity of other pollinators on cucumber

4.2.2 Foraging activity of Indian bee, *A. cerana* on cucumber

The foraging activity of *A. cerena* on cucumber was observed from 0800 to 1800 h from Ist week after 10 per cent flowering upto Vth week. The foraging activity during first week after 10 per cent flowering started at 0800 h with 3.80 bees/m^2/5 min and maximum was attained at 1000 h with 8.26 bees/m^2/5 min (Table 3). At 1200 and 16.00 h, the bee activity was declined with 5.12 and 5.55 bees/m^2/5 min, respectively. As the day advanced, the bee activity was further declined and later the foraging activity suddenly decreased at 1800 h with 2.15 bees/m^2/5 min.

During second week after 10 per cent flowering, the foraging activity started at 0800 h with 4.40 bees/m^2/5 min and suddenly increased at 1000 h with 10.56 bees/m^2/5 min. At 1200 h, the bee activity was declined with 8.40 bees/m^2/5 min and as the day advanced the bee activity was declined. The second peak was noticed at 1600 h with 5.20 bees/m^2/5 min and later foraging activity suddenly decreased at 1800 h with 3.30 bees/m^2/5 min.

During third week after 10 per cent flowering, the foraging activity of Indian bee commenced at 0800 h with 5.60 bees/m^2/5 min and maximum activity was observed at 1000 h with 12.56 bees/m^2/5 min. After 1000 h, foraging activity declined, but second peak was noticed at 1600 h with 6.40 bees/m^2/5 min and later suddenly decreased at 1800 h with 3.50 bees/m^2/5 min.

Similar trend was observed during fourth week after 10 per cent flowering. Bee activity started from 0800 h with 6.40 bees/m^2/5 min and peak activity of bees was noticed at 1000 h with 13.56 bees/m^2/5 min. The least activity was found at 1800 h with 2.80 bees/m^2/5 min.

Same trend was also noticed even during fifth week after 10 per cent flowering with peak bee activity at 1000 h with 12.00 bees/m^2/5 min and lowest bee activity was found at 1800 h with 2.25 bees/m^2/5 min.

On an average, total number of bees seen on cucumber plot was 180.79 bees/m^2/5 min after 10 per cent flowering. *A. cerana* foraging activity was noticed from 0800 to 1800 h of the day/with mean maximum foraging activity at 1000 h with 11.38 bees/m^2/5 min which was followed by a next peak at 1200 h with 8.02 bees/m^2/5 min. However, lowest bee foraging activity on cucumber flowers was observed at 1800 h of the day with average of 2.80 bees/m^2/5 min (Table 3).

There was no significant difference in the mean bee foraging activity on cucumber flowers observed at weekly interval which ranged from 4.61 to 7.04 bees/m^2/5 min.

4.2.3 Foraging activity of little bee, *A. florea* on cucumber

The foraging activity of *A. florea* on cucumber was observed from 0800 to 1800 h from 1st week upto 5th week after flowering. On 1st week after flowering, the foraging activity commenced from 0800 h with 2.80 bees/m^2/5 min and sudden increase in bee activity was noticed at 1000 and 1200 h with 10.35 and 14.85 bees/m^2/5 min, respectively and decline in the bee activity was noticed at 1400 h with 4.95 bees/m^2/5 min. Again 2nd peak was noticed at 1600 h of the day with 8.40 bees/m^2/5 min and least bee activity was noticed at 1800 h with 2.38 bees/m^2/5 min (Table 4).

During 2nd week after 10 per cent flowering, the activity started at 0800 h with 3.60 bees/m^2/5 min. Sudden increase in bee activity was observed at 1000 and 1200 h with 11.55 and 15.80 bees/m^2/5 min, respectively and decline in the bee activity was noticed as the day advanced. However, second peak of bee activity was noticed at 1600 h with 8.66 bees/m^2/5 min. The lowest bee activity next to 0800 h was noticed at 1800 h with 1.95 bees/m^2/5 min.

The foraging activity of the little bee commenced at 0800 h with 4.85 bees/m^2/5 min during 3rd week after 10 per cent flowering and increased from 1000 h. with peak foraging activity at 1200 h (17.30 bees/m^2/5 min). The lowest bee activity was noticed at 1800 h of the day with 2.00 bees/m^2/5 min.

Table 3. Foraging activity of *A. cerana* on cucumber

Time (hours)	Number of bees/m² (5 spots)/5 min						
	Ist week	IInd week	IIIrd week	IVth week	Vth week	Total	Mean
0800	3.80	4.40	5.60	6.40	4.50	24.70	4.94^{d}
1000	8.26	10.56	12.56	13.56	12.00	56.94	11.38^{a}
1200	5.15	8.40	8.65	9.00	8.90	40.10	8.02^{b}
1400	2.80	3.10	2.70	3.50	2.30	14.40	2.88^{e}
1600	5.55	5.20	6.40	7.00	6.80	30.95	6.19^{c}
1800	2.15	3.30	3.50	2.80	2.25	14.00	2.80^{e}
Total	27.71	34.96^{a}	39.41	42.26	36.75	180.79	
Mean	4.61^{a}	5.82^{a}	6.56^{a}	7.04^{a}	6.125^{a}		

Means followed by same alphabets do not differ significantly by DMRT at 0.05%

Table 4. Foraging activity of *A. florea* on cucumber

Time (hours)	Number of bees/m² (5 spots)/5 min						
	Ist week	IInd week	IIIrd week	IVth week	Vth week	Total	Mean
0800	2.80	3.60	4.85	3.70	3.40	18.35	3.67^{e}
1000	10.35	11.55	12.80	12.98	13.65	61.33	12.26^{b}
1200	14.85	15.80	17.30	16.45	15.25	79.65	15.93^{a}
1400	4.95	5.80	6.00	6.25	7.00	30.00	6.00^{d}
1600	8.40	8.66	8.40	8.80	7.40	41.66	8.33^{c}
1800	2.38	1.95	2.00	2.10	1.46	9.89	1.97^{f}
Total	43.73	47.36	51.35	50.28	48.16	240.88	
Mean	7.28^{a}	7.89^{a}	8.55^{a}	8.38^{a}	8.02^{a}		

Means followed by same alphabets do not differ significantly by DMRT at 0.05%

During 4th and 5th week after 10 per cent flowering, same trend was observed and bee activity commenced from 0800 h with 3.70 and 3.40 bees bees/m²/5 min, respectively. Maximum bee activity was found at 1200 h with 16.45 and 15.25 bees/m²/5 min on 4th and 5th week after 10 per cent flowering, respectively. The lowest bee activity was found at 1800 h of the day with 2.10 and 1.46 bees/m²/5 min on 4th and 5th week, respectively.

Totally, 240.88 little bees/m²/5 min. visited the cucumber field in a day during the present study. The foraging activity of *A. florea* was observed from 0800 to 1800 h of the day with significantly highest mean foraging bee activity at 1200 h with 15.93 bees/m²/5 min, which was followed by 12.26 bees/m²/5 min at 1000 h. However, significantly lowest bee foraging activity on cucumber flowers was observed at 1800 h of the day with 1.97 bees/m²/5 min (Table 4).

There was no significant difference in the mean bee foraging activity on cucumber flowers observed at weekly intervals and it ranged from 7.28 to 8.55 bees/m²/5 min.

4.2.4 Foraging activity of other pollinators on cucumber

The foraging activity of other pollinators on cucumber was observed from 0800 to 1800 h during first to fifth week after 10 per cent flowering. On first week after flowering, the foraging activity commenced from 0800 h with 4.36 pollinators/m²/5 min. Foraging activity was more or less uniform from 0800 to 1200 h which ranged from 4.36 to 5.26 pollinators/m²/5 min. Highest pollinators activity was observed during 1400 h with 5.40 pollinators/m²/5 min. However, lowest activity was observed during 1600 and 1800h with 3.84 and 2.85 pollinators/m²/5 min (Table 5).

During IInd week after 10 per cent flowering, the foranging activity started at 0800 h with 3.85 pollinators/m²/5 min and gradually increased at 1000 and 1200 h with 5.10 and 6.66 pollinators/m²/5 min, respectively and declined in the pollinator activity was observed as the day advanced. However, increased in the pollinators activity was noticed again at 1800 h with 4.05 pollinators/m²/5 min.

On third week after 10 per cent flowering, the foraging activity started at 0800 h with 4.01 pollinators/m²/5 min. Highest foraging activity of pollinators was noticed at 1000 h with 6.40 pollinators/m²/5 min. The activity was uniform from 1200 to 1400 h with 4.85 and 4.20 pollinators/m²/5 min, respectively. Lowest activity was observed during 1600 h with 2.68 pollinators/m²/5 min and again activity was slightly increased during 1800 h with 4.14 pollinators/m²/5 min.

During fourth week after 10 per cent flowering, the foraging activity started at 0800 h with 5.50 pollinators/m²/5 min. Peak activity was noticed during 1000 h with 10.85 pollinators/m²/5 min. Further, pollinators activity declined as the day advanced, and lowest activity was observed at 1800 h with 2.48 pollinators/m²/5 min.

On fifth week after 10 per cent flowering, foraging activity started at 0800 h with 4.90 pollinators/m²/5 min. The activity was uniform throughout the day which ranged from 2.98 to 4.85 pollinators/m²/5 min from 1000 to 1800 h of the day.

Totally, 137.61 pollinators other than honey bees visited the cucumber field in a day during the present study. When foraging activity of other pollinators was compared between different hours of the day, it started at 0800 h with an average of 4.52 pollinators/m²/5 min. Peak activity was noticed during 1000 h with 6.16 pollinators/m²/5 min. The foraging activity of other pollinators was uniform from 1200 to 1800 h with an average of 3.39 to5.61 pollinators/m²/5 min.

There was no significant difference in the mean for other pollinators on cucumber flowers observed at weekly intervals, which ranged from 3.97 to 5.48 pollinators/m²/5 min.

Table 5. Foraging activity of other pollinators on cucumber

Time (hours)	Number of other pollinator /m² 5 min						
	Ist week	IInd week	IIIrd week	IVth week	Vth week	Total	Mean
0800	4.36	3.85	4.01	5.50	4.90	22.62	4.52^{b}
1000	4.68	5.10	6.40	10.85	3.80	30.83	6.16^{a}
1200	5.26	6.66	4.85	6.46	4.85	28.08	5.61^{ab}
1400	5.40	4.85	4.20	3.25	3.86	21.56	4.31^{b}
1600	3.84	3.69	2.68	4.36	2.98	17.55	3.51^{b}
1800	2.85	4.05	4.14	2.48	3.45	16.97	3.39^{b}
Total	26.39	28.2	26.28	32.9	23.84	137.61	
Mean	4.39^{a}	4.70^{a}	4.38^{a}	5.48^{a}	3.97^{a}		

Means followed by same alphabets do not differ significantly by DMRT at 0.05%

4.2.5 Comparative foraging activity of different pollinators

The comparative foraging activity of different pollinators indicated that, foraging activity of pollinators commenced at 0800h with 3.62 pollinators/m²/5 min. The activity of pollinators gradually increased and attained the peak at 1200h with 9.07 pollinators/m²/5 min, followed by at 1000h with 8.62 pollinators/m²/5 min. At 1400h and 1600h all most same number of pollinators were recorded i.e. 4.08 and 5.11 pollinators/m²/5 min, respectively. The least activity of pollinators was recorded at 1800h of the day (2.55 pollinators/m²/5 min).

Among the pollinators, *A florea* was most predominant species with 8.03 bees/m²/5 min, followed by *A cerana* and other pollinators. The least activity of in Cucumber crop was recorded with 3.43 bees/m²/5 min (Table 6).

4.3 EFFECTIVENESS OF DIFFERENT BEE ATTRACTANTS IN ATTRACTING THE BEES IN CUCUMBER

4.3.1 Influence of attractants on visitation of *A. dorsata* on cucumber

Data pertaining to the influence of attractants in attracting *A. dorsata* on cucumber are presented in Table 7.

First spray

A day before spraying of attractants, bee activity ranged from 0.86 to 1.66 bees/m²/5 min, which did not differ significantly among the treatments. However, following the day after first spray, cacambe @ 10 per cent attracted higher number of bees (5.40 bees/m²/5 min), followed by jaggery solution @ 10 per cent and Bee-Q @ 1.25 per cent (4.45 and 3.86 bees/m²/5 min, respectively). The next best treatment was crop sprayed with sugar solution @ 10 per cent and sugarcane juice @ 10 per cent (2.75 and 2.48 bees/m²/5 min, respectively) and were on par with each other. Further, molasses @ 10 per cent attracted less number of bees than above treatments (2.10 bees/m²/5 min) and the open pollination plot without any spray was inferior with 1.25 bees/m²/5 min.

On 3rd day after the first spray, cacambe @ 10 per cent (5.69 bees/m²/5 min) was significantly superior in attracting more number of bees over the rest of the treatments. Next highest bee activity was recorded in the plot sprayed with jaggery solution @ 10 per cent and Bee-Q @ 1.25 per cent bees with 4.71 and 3.96 bees/m²/5 min, respectively. Treatment with sugarcane juice @ 10 per cent attracted 2.70 bees/m²/5 min, which was on par with the plot sprayed with sugar solution @ 10 per cent with (2.60 bees/m²/5 min). Lowest bees were observed in treatments with molasses @ 10 per cent (2.25 bees/m²/5 min) and untreated control (1.40 bees/m²/5 min).

On 5th day after first spray, once again cacambe @ 10 per cent recoded significantly higher number of bees (4.35 bees/m²/5 min). Further this treatment was followed by plot sprayed with jaggery solution @ 10 per cent and Bee-Q @ 1.25 per cent which attracted 4.20 and 3.28 bees/m²/5 min, respectively. The next best treatment was sugarcane juice @ 10 per cent (2.16 bees/m²/5 min) and was on par with sugar solution @ 10 per cent (2.00 bees/m²/5 min) and molasses @ 10 per cent (2.00 bees/m²/5 min). However, least number of bees were observed in crop without any spray (1.10 bees/m²/5 min).

Second spray

A day after second spray, treatment with cacambe @ 10 per cent (5.30 bees/m²/5 min) proved significantly superior over the rest of the treatments. Next best treatments were jaggery solution @ 10 per cent (4.58 bees/m²/5 min) and Bee-Q @ 1.25 per cent (3.45 bees/m²/5 min). Further, plot sprayed with sugarcane juice @ 10 per cent and sugar solution @ 10 per cent attracted more or less equal number of bees with 2.50 and 2.20 bees/m²/5 min, respectively. The open pollination without spray was inferior with 1.60 bees/m²/5 min.

Table 6. Comparative foraging activity of different pollinators on cucumber

Time hours	*A. dorsata*	*A. cerena*	*A. florea*	Others	Total	Mean
0800	1.56^{d}	4.94^{d}	3.67^{e}	4.52^{b}	14.48	3.62^{e}
1000	4.68^{b}	11.38^{a}	12.26^{b}	6.16^{a}	34.48	8.62^{b}
1200	6.72^{a}	8.02^{b}	15.93^{a}	5.61^{ab}	36.28	9.07^{a}
1400	3.15^{c}	2.88^{e}	6.00^{d}	4.31^{b}	16.34	4.08^{d}
1600	2.41^{cd}	6.19^{c}	8.33^{c}	3.51^{b}	20.44	5.11^{c}
1800	2.07^{d}	2.80^{e}	1.97^{f}	3.39^{b}	10.23	2.55^{f}
Total	20.59	36.21	48.16	27.5	132.25	
Mean	3.43^{d}	6.03^{b}	8.03^{a}	4.58^{c}		

Means followed by same alphabets do not differ significantly by DMRT at 0.05%

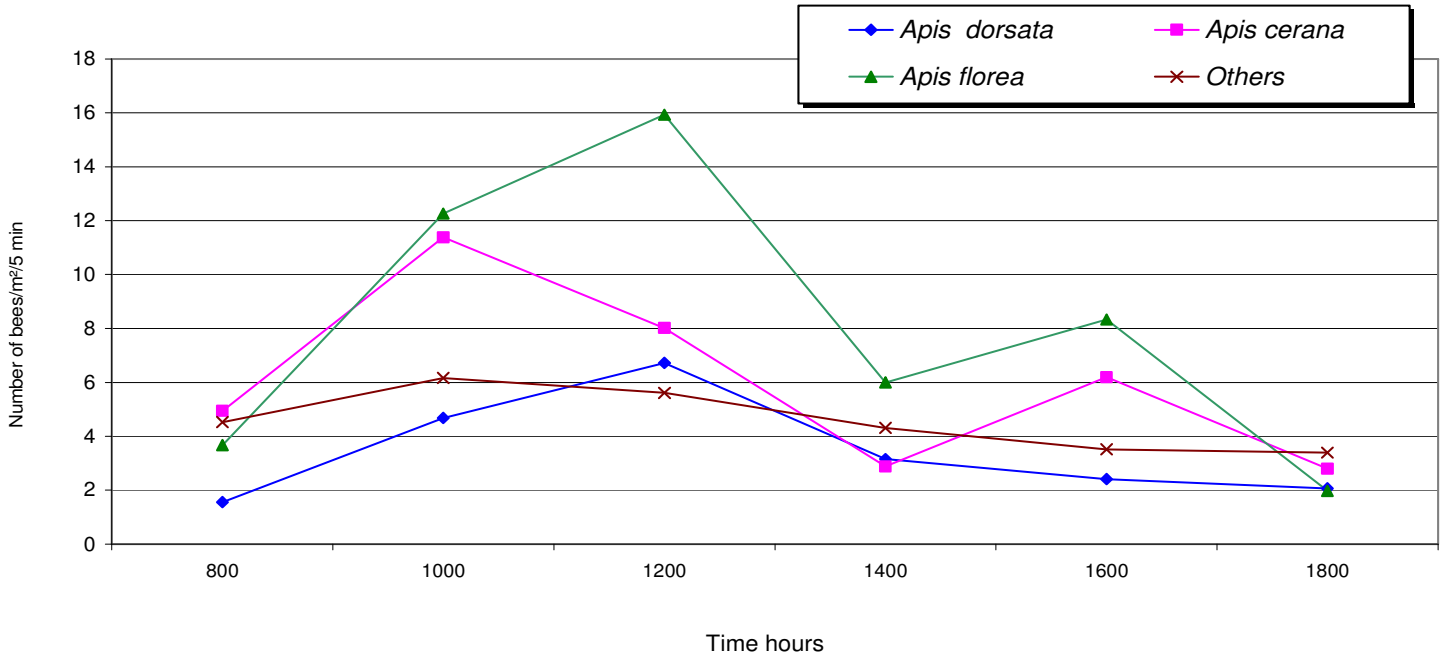

Fig. 3. Comparative foraging activity of different pollinators on cucumber

Fig. 3. Comparative foraging activity of different pollinators on cucumber

Table 7. Influence of attractants on visitation of *A. dorsata* on cucumber

Treatment	Bee visit to flower/ sq.mt./5 min									
	Ist spray				IInd spray			IIIrd spray		
	1 DBFS	1 DAFS	3 DAFS	5 DAFS	1 DASS	3 DASS	5 DASS	1 DATS	3 DATS	5 DATS
Cacambe @ 10%	1.04^{a}	5.40^{a}	5.69^{a}	4.35^{a}	5.30^{a}	6.00^{a}	5.80^{a}	5.98^{a}	6.25^{a}	5.35^{a}
Bee-Q @ 1.25 %	1.40^{a}	3.86^{ab}	3.96^{bc}	3.28^{ab}	3.45^{bc}	3.96^{bc}	3.30^{c}	3.80^{ab}	4.00^{abc}	3.85^{a}
Sugarcane juice @ 10%	1.66^{a}	2.48^{c}	2.70^{cd}	2.16^{bc}	2.50^{cd}	2.98^{cd}	2.60^{cd}	2.75^{b}	3.00^{bc}	2.80^{ab}
Sugar solution @ 10%	0.86^{a}	2.75^{bc}	2.60^{cd}	2.00^{cd}	2.20^{cd}	2.40^{d}	2.38^{cd}	2.45^{b}	2.75^{bc}	2.40^{bc}
Jaggery solution @ 10%	0.98^{a}	4.45^{a}	4.71^{ab}	4.20^{a}	4.58^{ab}	4.75^{ab}	4.46^{b}	4.50^{ab}	4.75^{ab}	4.60^{bc}
Molasses @ 10%	1.00^{a}	2.10^{cd}	2.25^{d}	2.00^{cd}	2.00^{d}	2.25^{d}	2.10^{d}	2.35^{b}	2.65^{c}	2.40^{bc}
Control (without any spray)	1.02^{a}	1.25^{d}	1.40e	1.10^{d}	1.60^{d}	2.10^{d}	1.80^{d}	2.00^{b}	2.20^{c}	2.10^{c}

DBFS- Days before first spray DAS- Days after spray DAFS-Day after first spray DASS- Day after second spray DATS-Day after third spray

Means followed by same alphabets do not differ significantly by DMRT at 0.05%

Among different treatments, spraying of cacambe 10 per cent was found to be superior compared to other treatments (6.00 bees/m²/5 min) on the 3rd day. The next best treatment was jaggery solution @ 10 per cent (4.75 bees/m²/5 min), followed by Bee-Q @ 1.25 per cent (3.96 bees/m²/5 min) and sugarcane juice @ 10 per cent (2.98 bees/m²/5 min). However, remaining treatments did not differ significantly with open pollination, which ranged from 2.10 to 2.40 bees/m²/5 min.

On 5th day after second spray, cacambe @ 10 per cent, jaggery solution @ 10 per cent and Bee-Q @ 1.25 per cent attracted maximum number of bees ranging from 3.30 to 5.80 bees/m²/5 min and were significantly superior over other treatments. Further, crop sprayed with sugarcane juice @ 10 per cent also attract maximum number of bees (2.60 bees/m²/5 min), but the open pollination plot was ineffective in attracting more bees.

Third spray

On 1st day after third spray, cacambe @ 10 per cent recorded significantly higher number of bees (5.98 bees/m²/5 min), followed by jagger solution @ 10 per cent (4.50 bees/m²/5 min), Bee-Q @ 1.25 per cent (3.80 bees/m²/5 min) and sugarcane juice @ 10 per cents (2.75 bees/m²/5 min) and significantly lower number of bees were observed in molasses @ 10 per cent (2.35 bees/m²/5 min) and untreated control (2.00 bees/m²/5 min).

On 3rd day after third spray, treatment cacambe @ 10 per cent attracted higher number of bees (6.25 bees/m²/5 min) and was on par with jaggery solution @ 10 per cent (4.75 bees/m²/5 min) and Bee-Q @ 1.25 per cent (4.00 bees/m²/5 min). The next best treatment was sugarcane juice @ 10 per cent (3.00 bees/m²/5 min) which was superior over sugar solution @ 10 per cent (2.75 bees/m²/5 min). The sugar solution was at par with molasses @ 10 per cent (2.65 bees/m²/5 min) and was found superior over untreated control.

On 5th day after third spray, cacambe @ 10 per cent was found superior (5.35 bees/m²/5 min) and next best treatments were jaggery solution @ 10 per cent and Bee-Q @ 1.25 per cent which attracted significantly higher number of bees with 4.60 and 3.85 bees/m²/5 min, respectively. Sugarcane juice @ 10 per cent was next best treatment which recorded 2.80 bees/m²/5 min. The remaining treatments did not differ significantly with the open pollination which ranged from 2.10 to 2.40 bees/m²/5 min.

4.3.2 Influence of attractants on visitation of *A. cerana* on cucumber

First spray

One day before spray, there was no significant difference in bee visitation among various treatments which ranged from 4.12 to 6.00 bees/m²/5 min (Table 8).

On one day after 1st spray, treatment with cacambe @ 10 per cent (8.86 bees/m²/5 min) was significantly superior in attracting more bees and was on par with Bee-Q @ 1.25 per cent (8.48 bees/m²/5 min). Further, jaggery @ 10 per cent was next best treatment which recorded 8.25 bees/m²/5 min, followed by 10 per cent sugar solution (6.12 bees/m²/5 min) and sugarcane juice (6.08 bees/m²/5 min). The remaining treatment attracted 5.28 bees/m²/5 min, which was significantly inferior to above treatments, but attracted more number of bees than control (4.80 bees/m²/5 min).

On 3rd day after first spray, the treatment sprayed with cacambe @ 10 per cent (12.68 bees/m²/5 min) was significantly superior in attracting more bees, followed by Bee-Q @ 1.25 per cent (10.80 bees/m²/5 min) and jaggery solution @ 10 per cent (9.75 bees/m²/5 min). However, sugarcane juice @ 10 per cent and sugar solution @ 10 per cent were the next best treatments with 7.85 and 7.00 bees/m²/5 min, respectively, followed by molasses @ 10 per cent (5.12 bees/m²/5 min) and were at par with untreated control (5.00 bees/m²/5 min).

On 5th day after first spray, treatment cacambe @ 10 per cent, Bee-Q @ 1.25 per cent and jaggery solution @ 10 per cent were found significantly superior in attracting more

Table 8. Influence of attractants on visitation of *A.cerana* on cucumber

Treatment	Bee visit to flower/ sq.mt./5 min									
	Ist spray				IInd spray			IIIrd spray		
	1 DBFS	1 DAFS	3 DAFS	5 DAFS	1 DASS	3 DASS	5 DASS	1 DATS	3 DATS	5 DATS
Cacambe @ 10%	5.34^{a}	8.86^{a}	12.68^{a}	11.25^{a}	13.85^{a}	19.03^{a}	14.50^{a}	17.00^{a}	18.14^{a}	15.05^{a}
Bee-Q @ 1.25 %	5.15^{a}	8.48^{a}	10.80^{ab}	8.75^{b}	10.98^{ab}	13.20^{b}	11.75^{ab}	14.33^{ab}	14.75^{ab}	12.57^{ab}
Sugarcane juice @ 10%	4.12^{a}	6.08^{bc}	7.85^{bc}	6.17^{cd}	6.85^{c}	9.15^{cd}	8.00^{cd}	10.75^{bc}	10.98^{cd}	9.15^{bcd}
Sugar solution @ 10%	5.01^{a}	6.12^{bc}	7.00^{cd}	6.00^{cd}	6.00^{c}	9.00^{cd}	7.88^{cd}	10.00^{cd}	10.75^{cd}	9.00^{bcd}
Jaggery solution @ 10%	5.85^{a}	8.25^{ab}	9.75^{abc}	7.85^{bc}	9.85^{b}	11.26^{bc}	10.50^{bc}	12.26^{bc}	12.86^{bc}	11.00^{bc}
Molasses @ 10%	6.00^{a}	5.28^{c}	5.12^{d}	4.95^{de}	6.45^{c}	7.50^{d}	7.00^{d}	9.00^{cd}	9.15^{de}	7.75^{cd}
Control (without any spray)	5.75^{a}	4.80^{c}	5.00^{d}	4.00^{e}	5.50^{c}	7.00^{d}	6.25^{d}	7.00^{d}	7.25^{e}	6.52^{d}

DBFS- Days before first spray DAS- Days after spray DAFS-Day after first spray DASS- Day after second spray DATS-Day after third spray

Means followed by same alphabets do not differ significantly by DMRT at 0.05%

number of bees that ranged from 7.85 to 11.25 bees/m²/5 min. This was followed by 10 per cent sugarcane juice (6.17 bees/m²/5 min) which was on par with sugar solution @ 10 per cent (6.00 bees/m²/5 min) and least number of bees recorded in untreated control (4.00 bees/m²/5 min).

Second spray

A day after second spray, treatment with cacambe @ 10 per cent (13.85 bees/m²/5 min) proved significantly superior over the rest of the treatments. Next best treatments were Bee-Q @ 1.25 per cent (10.98 bees/m²/5 min) and jaggery solution @ 10 per cent (9.85 bees/m²/5 min). These were followed by sugarcane juice (10%), molasses (10%) and sugar solution (10%) which attracted bees ranging from 6.00 to 6.85 bees/m²/5 min. The open pollination without spray was infeor with with 5.50 bees/m²/5 min.

Among the different treatments, spraying of cacambe 10 per cent was found to be superior compared to other treatments (19.03 bees/m²/5 min) on the 3rd day. Bee-Q (1.25%) was next best treatment with 13.20 bees/m²/5 min, followed by jaggery solution @ 10 per cent (11.26 bees/m²/5 min). However, sugarcane juice (10%) and sugar solution (10%) attracted 9.15 and 9.00 bees/m²/5 min, respectively and were on par with each other and superior over molasses @ 10 per cent (7.50 bees/m²/5 min) and untreated control (7.00 bees/m²/5 min).

On 5th day after second spray cacambe (10%), Bee-Q (1.25)% and jaggery solution (10%) attracted maximum number of bees that ranged from 10.50 to 14.50 bees/m²/5 min and were significantly superior over the other treatments. The next best treatment were sugarcane juice (10%) and sugar solution (10%). However, molasses @ 10 percent (7.00 bees/m²/5 min) was also successful in attracting more bees over control (6.25 bees/m²/5 min).

Third spray

Treatment with cacambe @ 10 per cent was significantly superior in attracting more bees (17.00 bees/m²/5 min), followed by Bee-Q @ 1.25 per cent (14.33 bees/m²/5 min), on first day ater third spray. Further, jaggery solution @ 10 per cent (12.26 bees/m²/5 min) was the next best treatment, followed by sugar cane juice @ 10 per cent (10.75 bees/m²/5 min). The remaining treatments attracted the bees that ranged from 9.00 to 10.00 bees/m²/5 min and were found inferior to above treatments, but significantly superior in attracting more number of bees than control (7.00 bees/m²/5 min). On 3rd day after third spray, the treatment cacambe @ 10 per cent (18.14 bees/m²/5 min) was significantly superior in attracting more bees, followed by Bee-Q @ 1.25 per cent (14.75 bees/m²/5 min) and jaggery solution @ 10 per cent (12.86 bees/m²/5 min). Sugarcane juice (10%) was next best treatment which recorded 10.98 bees/m²/5 min and was on par with sugar solution @ 10 per cent (10.75 bees/m²/5 min). Molasses @ 10 per cent (9.15 bees/m²/5 min) failed to attract more number of bees, but significantly superior over control plot (7.25 bees/m²/5 min).

On 5th day after third spray, more number of bees were attracted in the treatments with cacambe @ 10 per cent (15.05 bees/m²/5 min), Bee-Q @ 1.25 per cent (12.57 bees/m²/5 min) and jaggery @ 10 per cent (11.00 bees/m²/5 min) and were significantly superior over the other treatments. The treatments with sugarcane juice @ 10 per cent (9.15 bees/m²/5 min) was next best treatment which was on par with sugar solution @ 10 per cent (9.00 bees/m²/5 min). Further, crop sprayed with molasses (10%) also attracted more number of bees (7.75 bees/m²/5 min) which was inferior to above treatments, but superior than control plot (6.52 bees/m²/5 min).

4.3.3 Influence of attractants on visitation of *A. florea* on cucumber

First spray

A day before first spray, the number of bee visiting the cucumber flowers ranged from 0.33 to 0.90 bees/m²/5 min and did not differ significantly among the treatments. A day after first spray, cacambe @ 10 per cent attracted more number of bees (4.50 bees/m²/5 min) and was significantly superior over rest of the treatments except Bee-Q @ 1.25 per cent (3.65

Table 9. Influence of attractants on visitation of *A. florea* on cucumber

Treatment	Bee visit to flower/ sq.mt./5 min									
	Ist spray				IInd spray			IIIrd spray		
	1 DBFS	1 DAFS	3 DAFS	5 DAFS	1 DASS	3 DASS	5 DASS	1 DATS	3 DATS	5 DATS
Cacambe @ 10%	0.75^{a}	4.50^{a}	5.00^{a}	4.10^{a}	4.65^{a}	5.50^{a}	4.00^{a}	4.85^{a}	5.40^{a}	4.50^{a}
Bee-Q @ 1.25 %	0.73^{a}	3.65^{ab}	3.82^{ab}	3.66^{ab}	3.20^{b}	4.00^{b}	2.85^{bc}	4.10^{ab}	4.55^{ab}	4.00^{ab}
Sugarcane juice @ 10%	0.90^{a}	2.45^{c}	2.65^{bcd}	2.33^{cd}	2.56^{bc}	3.50^{b}	2.40^{cd}	2.50^{cd}	3.00^{bcd}	2.45^{bc}
Sugar solution @ 10%	0.80^{a}	2.60^{c}	3.40^{bc}	2.39^{cd}	2.80^{cd}	3.75^{b}	2.80^{bc}	3.00^{bcd}	3.65^{abc}	3.45^{abc}
Jaggery solution @ 10%	0.60^{a}	3.00^{bc}	2.93^{bc}	2.84^{bc}	3.00^{cd}	3.80^{b}	3.55^{ab}	3.45^{abc}	3.85^{abc}	3.30^{abc}
Molasses @ 10%	0.73^{a}	2.20^{cd}	2.39^{cd}	2.10^{cd}	2.00^{cd}	2.56^{c}	2.20^{cd}	2.40^{cd}	2.75^{cd}	2.55^{bc}
Control (without any spray)	0.33^{a}	1.65^{d}	1.60^{d}	1.60^{d}	1.60^{d}	2.00^{c}	1.90^{d}	2.00^{d}	2.09^{d}	2.00^{c}

DBFS- Days before first spray DAS- Days after spray DAFS-Day after first spray DASS- Day after second spray DATS-Day after third spray

Means followed by same alphabets do not differ significantly by DMRT at 0.05%

bees/m²/5 min), followed by jaggery solution @ 10 per cent (3.00 bees/m²/5 min). However, sugar solution @ 10 per cent recorded 2.60 bees/m²/5 min which was on par with sugarcane juice @ 10 per cent (2.45 bees/m²/5 min). Further, molasses (10%) attracted least number of bees (2.20 bees/m²/5 min) and was inferior over rest of the treatment, but superior over control (1.65 bees/m²/5 min) (Table 9).

On 3rd day after first spray, 10 per cent cacambe recorded maximum number of bees (5.00 bees/m²/5 min), followed by Bee-Q @ 1.25 per cent (3.82 bees/m²/5 min). Further, sugar solution @ 10 per cent (3.40 bees/m²/5 min) was next best treatment in attracting bees. This was followed by crop sprayed with jaggery solution @ 10 per cent which recorded 2.93 bees/m²/5 min and 10 per cent sugarcane juice (2.65 bees/m²/5 min). Whereas, molasses @ 10 per cent recorded 2.39 bees/m²/5 min which found superior over untreated control (1.60 bees/m²/5 min).

On 5th day after first spray, once again cacambe (10%) recorded significantly higher number of bee (4.10 bees/m²/5 min). The next best treatments were Bee-Q @ 1.25 per cent (3.66 bees/m²/5 min) and jaggery solution @ 10 per cent (2.84 bees/m²/5 min). Further, sugar solution @ 10 per cent recorded 2.39 bees/m²/5 min, which was on par with crop spray with 10 per cent sugarcane juice and 10 per cent molasses which recorded 2.33 and 2.10 bees/m²/5 min, respectively and these were found superior over untreated control which recorded 1.60 bees/m²/5 min.

Second spray

A day after second spray, treatment with cacambe @ 10 per cent (4.65 bees/m²/5 min) proved significantly superior over rest of the treatment. The next best treatment was 1.25 per cent Bee-Q (3.20 bees/m²/5 min). However, remaining treatments attracted equal number of bees that ranged from 2.00 to 3.00 bees/m²/5 min and least bees were found in untreated control (1.60 bees/m²/5 min).

On 3rd day after second spray, once again crop sprayed with cacambe @ 10 per cent (5.50 bees/m²/5 min) was significantly superior in attracting more bees. However, Bee-Q (1.25%), jaggery (10%), sugar solution (10%) and sugarcane juice (10%) recorded 4.00, 3.80, 3.75 and 3.50 bees/m²/5 min, respectively which were on par with each other and molasses @ 10 per cent (2.56 bees/m²/5 min) was superior over untreated control (2.00 bees/m²/5 min), but inferior to above treatments.

On 5th day after second spray, 10 per cent cacambe recorded 4.00 bees/m²/5 min and was significantly superior over other treatments, followed by jaggery solution @ 10 per cent (3.55 bees/m²/5 min), Bee-Q @ 1.25 per cent (2.85 bees/m²/5 min) and sugar solution @ 10 per cent (2.80 bees/m²/5 min). However, 10 per cent sugarcane juice recorded 2.40 bees/m²/5 min, which was on par with molasses @ 10 per cent (2.20 bees/m²/5 min) and least bees were recorded in untreated control with 1.90 bees/m²/5 min.

Third spray

Treatment with cacambe @ 10 per cent (4.85 bees/m²/5 min) was significantly superior in attracting more bees, followed by Bee-Q @ 1.25 per cent (4.10 bees/m²/5 min) on first day after third spray. Further, jaggery solution @ 10 per cent (3.45 bees/m²/5 min) was the next best treatment which was followed by sugar solution @ 10 per cent (3.00 bees/m²/5 min). The treatment with 10 per cent sugarcane juice @ 10 per cent recorded 2.50 bees/m²/5 min which was on par with 10 per cent molasses (2.40 bees/m²/5 min) and was superior over untreated control (2.00 bees/m²/5 min).

On 3rd day after third spray, cacambe 10 per cent (5.40 bees/m²/5 min) proved significantly superior over rest of the treatments, which attracted maximum number of bees, followed by Bee-Q (4.55 bees/m²/5 min). Further, treatment with jaggery solution @ 10 per cent recorded 3.85 bees/m²/5 min which was on par with sugar solution @ 10 per cent (3.65 bees/m²/5 min). However, crop sprayed with sugarcane juice @ 10 per cent recorded more number of bees (3.00 bees/m²/5 min) which was at par with 10 per cent molasses (2.75

bees/m²/5 min). The untreated control failed to attract more bees and significantly inferior to above treatment (2.09 bees/m²/5 min).

On 5th day after third spray, cacambe (10%) was found superior (4.50 bees/m²/5 min) and next best treatment was Bee-Q @ 1.25 per cent (4.00 bees/m²/5 min). Further, sugar solution (10%) also recorded more number of bees (3.45 bees/m²/5 min) which was on par with jaggery solution @ 10 per cent (3.30 bees/m²/5 min). Molasses @ 10 per cent was next best treatment with 2.55 bees/m²/5 min and was on par with sugarcane juice @ 10 per cent with 2.45 bees/m²/5 min and was superior to untreated control (2.00 bees/m²/5 min).

4.3.4 Influence of attractants on visitation of other pollinators on cucumber

First spray

A day before first spray, the number of other pollinator visiting the cucumber flowers ranged from 0.36 to 0.79 pollinators/m²/5 min and did not differ significantly among treatments. A day after first spray, cacambe (10%), jaggery solution (10%), Bee-Q (1.25%) and sugar solution (10%) attracted maximum number of pollinators which ranged from 1.40 to 1.57 pollinators/m²/5 min and were on par with each other. However, molasses @ 10 per cent (0.78 pollinators/m²/5 min) was as good as untreated control in attracting other pollinators (0.40 pollinators/m²/5 min) (Table 10).

On 3rd day after first spray, more number of other pollinators (3.10 pollinators/m²/5 min) were attracted in the treatment with cacambe (10%), which was significantly superior over other treatments except 1.25 per cent Bee-Q @ 1.25 per cent (2.46 pollinators/m²/5 min) and jaggery solution @ 10 per cent (2.10 pollinators/m²/5 min). However, sugar solution @ 10 per cent (1.73 pollinators/m²/5 min) was the next best treatment, which was at par with sugarcane juice @ 10 per cent (1.70 pollinators/m²/5 min). Further, molasses @ 10 per cent did not differ significantly with untreated control.

On 5th day after first spray, cacambe @ 10 per cent (2.12 pollinators/m²/5 min) attracted significantly higher number of bees and was on par with jaggery (10%), Bee-Q (1.25%), sugarcane juice (10%) and sugar solution (10%) which attracted pollinators that ranged from 1.57 to 1.83 pollinators/m²/5 min. However, molasses (10%) record least number of pollinators (1.00 pollinators/m²/5 min) which was significantly superior over untreated control (0.61 pollinators/m²/5 min).

Second spray

One day after second spray, cacambe @ 10 per cent attracted maximum number of pollinators (3.16 pollinators/m² 5 min), followed by the treatment with jaggery solution (10%), Bee-Q (1.25%), sugar solution (10%) and sugarcane juice (10%) who attracted equal number of pollinators that ranged from 2.20 and 2.80 p pollinators/m²/5 min. Further, molasses (10%) recorded more pollinators (1.78 pollinators/m²/5 min) and was inferior to above treatments, but significantly superior over untreated control (1.00 pollinators/m²/5 min).

Among different treatments, spraying of cacambe 10 per cent was found to be superior compared to other treatments (4.37 pollinators/m²/5 min) on the 3rd day. The next best treatment was Bee-Q @ 1.25 per cent (3.61 pollinators/m²/5 min) which was on par with jaggery solution @ 10 per cent (3.40 pollinators/m²/5 min). Further, sugar solution (10%) which recorded 2.81 pollinators/m²/5 min was at par with 10 per cent sugarcane juice (2.60 pollinators/m²/5 min). However, molasses @ 10 per cent attracted 2.10 pollinators/m²/5 min which was at par with untreated control plot (1.40 pollinators/m²/5 min).

On 5th day after second spray, treatment with cacambe @ 10 per cent recorded 3.10 pollinators/m²/5 min, followed by Bee-Q (1.25%) and jaggery solution (10%) with 2.53 and 2.36 pollinators/m²/5 min, respectively. Ten per cent sugar solution also attracted more pollinators which was on par with sugarcane juice (10%) and molasses (10%), whereas control plot failed to attract more pollinators (1.38 pollinators/m²/5 min).

Table 10. Influence of attractants on visitation of Other pollinators on cucumber

Treatment	Bee visit to flower/ sq.mt./5 min									
	Ist spray				IInd spray			IIIrd spray		
	1 DBFS	1 DAFS	3 DAFS	5 DAFS	1 DASS	3 DASS	5 DASS	1 DATS	3 DATS	5 DATS
Cacambe @ 10%	0.78^{a}	1.57^{a}	3.10^{a}	2.12^{a}	3.16^{a}	4.37^{a}	3.10^{a}	4.85^{a}	5.10^{a}	4.48^{a}
Bee-Q @ 1.25 %	0.36^{a}	1.40^{ab}	2.46^{ab}	1.68^{a}	2.73^{ab}	3.61^{ab}	2.53^{ab}	3.70^{ab}	3.95^{ab}	3.18^{b}
Sugarcane juice @ 10%	0.58^{a}	1.00^{ab}	1.70^{b}	1.65^{a}	2.20^{ab}	2.60^{bc}	1.93^{bc}	2.89^{bc}	3.00^{bc}	2.68^{bc}
Sugar solution @ 10%	0.49^{a}	1.40^{ab}	1.73^{b}	1.57^{a}	2.48^{ab}	2.81^{bc}	1.98^{bc}	2.76^{bc}	3.10^{bc}	2.41^{bc}
Jaggery solution @ 10%	0.66^{a}	1.50^{a}	2.10^{ab}	1.83^{a}	2.80^{a}	3.40^{ab}	2.36^{ab}	3.40^{b}	3.68^{abc}	3.00^{bc}
Molasses @ 10%	0.68^{a}	0.78^{bc}	0.81^{c}	1.00^{b}	1.78^{b}	2.10^{cd}	1.80^{bc}	2.00^{c}	2.48^{c}	2.10^{c}
Control (without any spray)	0.79^{a}	0.40^{c}	0.68^{c}	0.61^{b}	1.00^{c}	1.40^{d}	1.38^{c}	1.10^{d}	1.35^{d}	1.00^{d}

DBFS- Days before first spray DAS- Days after spray DAFS-Day after first spray DASS- Day after second spray DATS-Day after third spray

Means followed by same alphabets do not differ significantly by DMRT at 0.05%

Third spray

One day after third spray, cacambe (10%) attracted higher number of pollinators (4.85 pollinators/m²/5 min), followed by treatments Bee-Q (1.25%) and jaggery (10%) which were significantly superior over rest of the treatments (3.70 and 3.40 pollinators/m²/5 min, respectively). Next best treatment was sugarcane juice @ 10 per cent (2.89 pollinators/m²/5 min) which was followed by sugar solution 10 per cent (2.76 pollinators/m²/5 min). Further, plot sprayed with molasses (10%) was least effective than other, but superior over untreated control.

Maximum number of pollinators were observed in cacambe (10%) treated plot (5.10 pollinators/m²/5 min) on 3rd day after third spray. This was significantly superior over others and was followed by Bee-Q @ 10 per cent (3.95 pollinators/m²/5 min) and jaggery solution @ 10 per cent (3.68 pollinators/m²/5 min). However, 10 per cent sugar solution (3.10 pollinators/m²/5 min) which was on par with sugarcane juice @ 10 per cent (3.00 pollinators/m²/5 min), but superior over molasses (10%) which recorded least number of pollinators (2.48 pollinators/m²/5 min). However, this was superior than untreated control plot (1.35 pollinators/m²/5 min).

On 5th day after third spray, once again 10 per cent cacambe attracted maximum number of pollinators (4.48 pollinators/m²/5 min) which was significantly superior over rest of the treatments, followed by Bee-Q (1.25%) with 3.18 pollinators/m²/5 min. Further, treatment with jaggery solution (10%), sugarcane juice (10%) and sugar solution (10%) were equally effective which attracted pollinators that ranged from 2.41 to 3.00 pollinators/m²/5 min. However, molasses (10%) was inferior, other treatment with 2.10 pollinators/m²/5 min, but superior over untreated control plot (1.00 pollinators/m²/5 min).

4.4 INFLUENCE OF BEE POLLINATION ON QUALITATIVE AND QUANTITATIVE PARAMETERS OF CUCUMBER

Data on effect of bee pollination on yield parameters *viz*., number of flowers/plant, per cent fruit set, number of healthy and malformed fruits/plant, length and diameter of fruit, number of fruits/plant, weight of each fruit, net plot yield and converted yield per ha are presented in Table 11 .

4.4.1 Influence on qualitative parameters

4.4.1.1 Number of Male and Female flowers per plant

All the treatments which received attractants did not differ significantly with the open pollination and caged crop in terms of number of male and female flowers per plant which ranged from 293.76 to 351.05 and 17.20 to 20.94, respectively (Table 11).

4.4.1.2 Per cent fruit set

The spraying of cacambe (10%) was found to be superior in per cent fruit set (94.66), which resulted in 115.52 and 308.25 per cent increase over open pollination without any spray and caged without bees, respectively. However, this treatment was followed by sugar solution @ 10 per cent (77.96) which was on par with Bee-Q @ 1.25 per cent (77.39) and jaggery solution @ 10 per cent (75.26). Further, crop sprayed with sugarcane juice @ 10 per cent recorded 58.33 per cent of fruit set which was on par with crop caged with bees (51.79) and by molasses @ 10 per cent (57.64).

The least number of per cent fruit set were recorded in the treatments like open pollination without any spray (43.92) and caged with bees (23.18) (Table 11).

4.4.1.3 Healthy fruit per plant

Number of healthy fruits per plant was significantly higher in crop received cacambe @ 10 per cent (17.22 fruits/plant) which was followed by jaggery solution @ 10 per cent (11.25 fruits/plant) which was significantly at par with plot sprayed with Bee-Q @ 1.25 per cent (10.19 fruits/plant). However, remaining treatments recorded significantly equal number

Table 11. Influence of bee pollination on qualitative parameters of cucumber

Treatments	Number of male flowers/ plant	Number of female flowers/ plant	Per cent fruit set	% increase over control (open pollination)	% Increase over control (Caged without bees)	Healthy fruits	% increase over control (open pollination)	%Increase over control (Caged without bees)
Caged with bees	293.76[a]	17.28[a]	51.79[c]	17.91	123.42	4.94[d]	64.66	-
Caged without bees	298.94[a]	17.25[a]	23.18[e]	-47.22	-	0.00[f]	00.00	-
Cacambe @ 10%	321.12[a]	20.07[a]	94.66[a]	115.52	308.36	17.22[a]	474.00	-
Bee-Q @ 1.25%	307.53[a]	18.09[a]	77.39[b]	76.20	233.86	10.19[b]	239.66	-
Sugarcane juice @ 10%	351.05[a]	20.41[a]	58.33[c]	32.80	151.63	6.90[c]	130.00	-
Sugar solution @ 10%	290.68[a]	17.20[a]	77.96[b]	77.50	236.32	9.00[bc]	200.00	-
Jaggery solution @ 10%	335.04[a]	20.94[a]	75.26[b]	71.35	224.67	11.25[b]	275.00	-
Molasses @ 10%	299.03[a]	17.59[a]	57.64[cd]	31.23	148.66	5.11[cd]	70.33	-
Open pollination	320.16[a]	20.01[a]	43.92[d]	-	89.47	3.00[e]	-	-

Means followed by same alphabets do not differ significantly by DMRT at 0.05%

Table 11. Contd……..

Treatments	Mal formed fruits/ plant	% decrease over control (open pollination)	% Increase over control (Caged without bees)	Length of the fruits (cm)	% increase over control (open pollination)	% Increase over control (Caged without bees)	Diameter of fruits (cm)	% increase over control (open pollination)	% Increase over control (Caged without bees)
Caged with bees	4.01^{d}	-30.74	0.25	18.50^{cd}	20.91	37.03	4.20^{bc}	5.00	7.69
Caged without bees	4.00^{d}	-30.91	-	13.50^{f}	-11.76	-	3.90^{c}	-2.50	-
Cacambe @ 10%	1.78^{e}	-69.25	-55.50	22.00^{a}	43.79	62.96	5.70^{a}	42.50	46.15
Bee-Q @ 1.25%	3.81^{d}	-34.19	-4.75	20.40^{ab}	33.33	51.11	5.00^{ab}	25.00	28.20
Sugarcane juice @ 10%	5.00^{b}	-13.64	25.00	18.20^{d}	18.95	34.81	4.40^{bc}	10.00	12.82
Sugar solution @ 10%	4.41^{c}	-23.83	57.75	18.00^{d}	17.64	33.33	4.10^{c}	2.50	5.12
Jaggery solution @ 10%	4.51^{c}	-22.10	12.75	20.00^{bc}	30.71	48.14	5.50^{a}	37.50	41.02
Molasses @ 10%	5.03^{b}	-13.12	25.75	17.00^{d}	11.11	25.92	4.00^{c}	0.00	2.56
Open pollination	5.79^{a}	-	44.75	15.30^{e}	-	13.33	4.00^{c}	-	2.56

Means followed by same alphabets do not differ significantly by DMRT

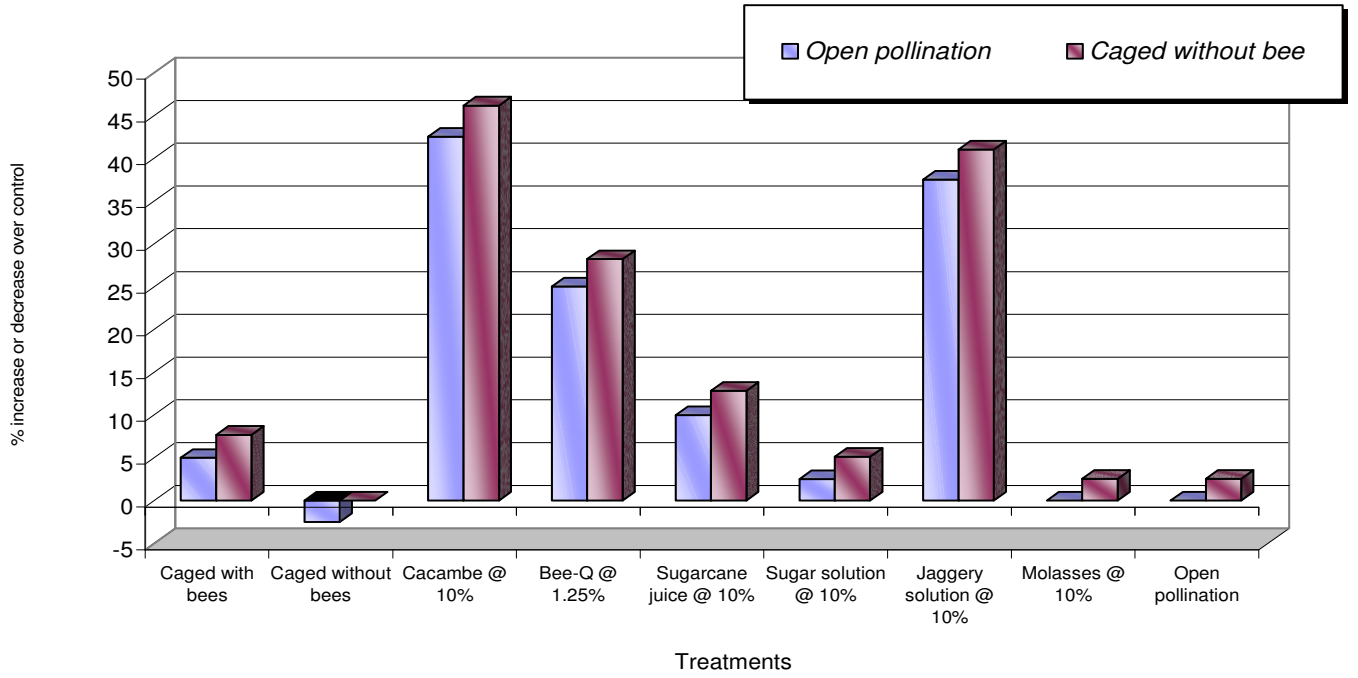

Fig. 4. Influence of bee pollination on qualitative parameters of cucumber (diameter of the fruit)

Fig. 4: Influence of bee pollination on qualitative parameters of cucumber (diameter of the fruit)

Table 12. Influence of bee pollination on quantitative parameters of cucumber

	Number of fruit/plant	% increase or decrease over control (open pollination)	% Increase over control (Caged without bee)	Weight of each fruit	% increase over control (open pollination)	% increase over control (Caged without bees)
Caged with bees	8.95[bc]	1.82	123.75	100.60[d]	4.35	44.89
Caged without bees	4.00[c]	-54.49	-	69.43[e]	-27.97	-
Cacambe @ 10%	19.00[a]	116.15	375.00	128.10[a]	32.88	84.50
Bee-Q @ 1.25%	14.00[ab]	59.27	250.00	123.20[ab]	27.80	77.44
Sugarcane juice @ 10%	11.90[ab]	35.38	197.50	114.10[bc]	18.36	64.33
Sugar solution @ 10%	13.41[ab]	52.55	235.25	116.80[abc]	21.16	68.22
Jaggery solution @ 10%	15.76[ab]	79.29	294.00	120.80[abc]	25.31	73.98
Molasses @ 10%	10.14[b]	15.35	153.50	108.50[cd]	12.55	56.27
Open pollination	8.79[bc]	-	119.75	96.40[d]	-	38.84

Means followed by same alphabets do not differ significantly by DMRT at 0.05%

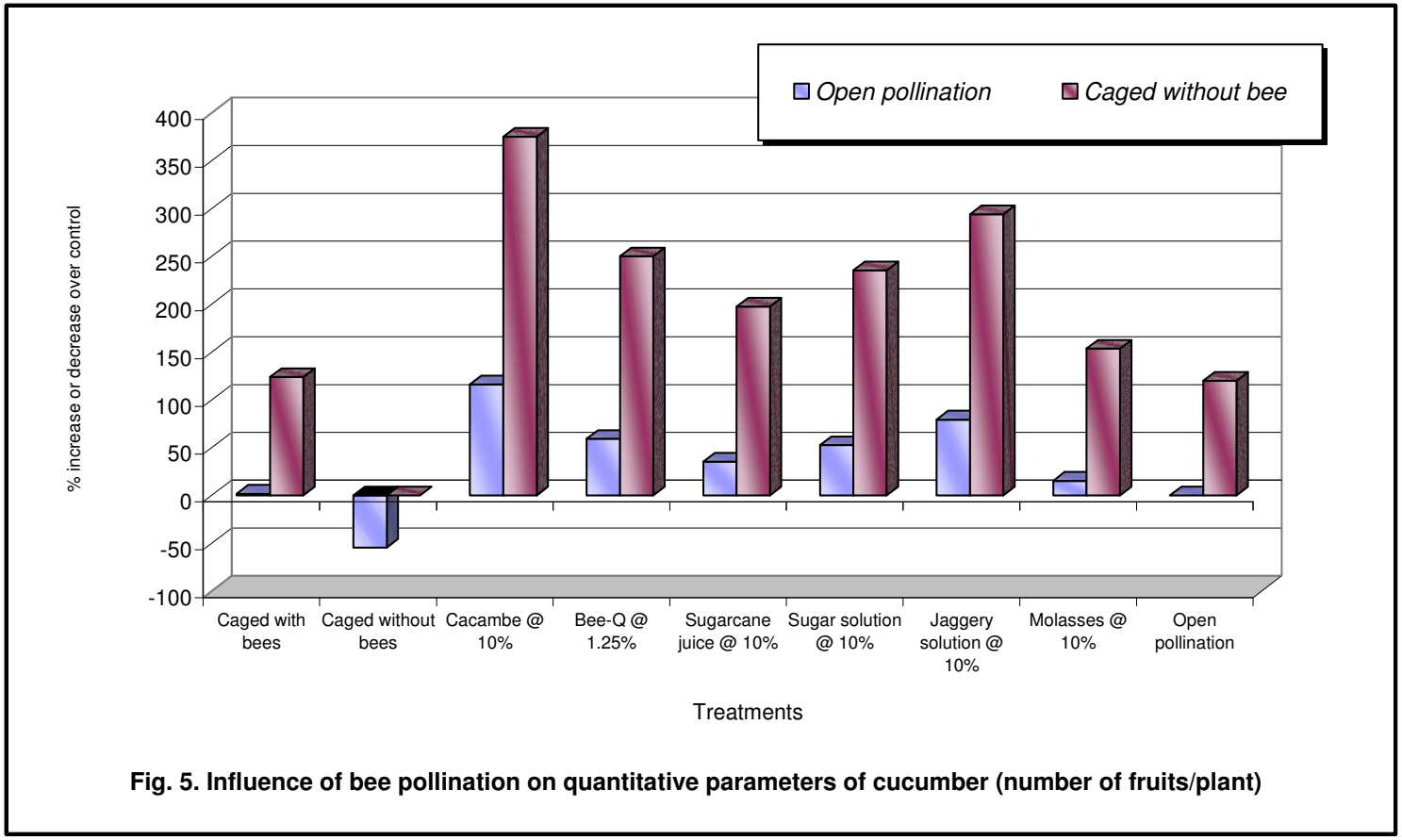

Fig. 5. Influence of bee pollination on quantitative parameters of cucumber (number of fruits/plant)

Fig. 5. Influence of bee pollination on quantitative parameters of cucumber (number of fruits / plant)

of healthy fruits which ranged from 5.11 to 9.00 fruits per plant. Further, plant caged without bees recorded zero number of healthy fruits per plant (Table 11).

4.4.1.4 Malformed fruits per plant

Crop with open pollination recorded more number of malformed fruits per plant (5.79 fruits/plant) which accounted for increase of in 44.75 per cent over caged crop without bees and was followed by mollases @ 10 per cent (5.03 fruit/plant). Whereas, cacambe @ 10 per cent recorded significantly lower number of malformed fruits (1.78 fruits/plant) which accounted for decrease of 69.25 and 55.55 per cent over open pollination without spray and caged without bees, respectively (Table 11) .

4.4.1.5 Fruit length

Length of the fruit was highest in cacambe sprayed plot (22.00 cm) which accounted for increase of 43.79 and 62.96 in per cent over open pollination without spray and caged without bees, respectively. This was on par with Bee-Q spray and jaggery solution spray which produced significantly superior fruits length. The rest of the treatments failed to increase the fruits length and were on par with open pollinated plot without spray, but superior over caged without bees (Table 11).

4.4.1.6 Fruits diameter

The spraying of cacambe @ 10 per cent was found to be superior as it recorded maximum diameter of fruits 5.70 cm, which resulted in 42.50 and 46.15 per cent increase over open pollination without any spray and caged plot without bees, respectively. However, this treatment was at par with other treatments except crop caged without bees(3.90 cm/fruit), open pollinated plot without any spray (4.00 cm/fruit), crop sprayed with molasses @ 10 per cent (4.00 cm/fruit) and crop sprayed with sugar solution (4.01 cm/fruit) (Table 11).

4.4.2 Influence on quantitative parameters

4.4.2.1 Number of fruits per plant

Open pollinated crop sprayed with cacambe (10%) produced significantly higher number (19.00 fruits/plant) which accounted for increase in the number of fruits to the tune of 116.15 and 375.00 per cent over open pollinated crop without spray and caged plot without bees, respectively. Further, it was followed by jaggery solution (10%) which produced more number (15.76 fruits/plant) with an increase of 79.29 and 294.00 per cent over open pollinated crop without spray and caged plot without bees and was on par with Bee-Q @ 1.25 per cent (14.00 fruits/plant), sugar solution @ 10 per cent (13.41 fruits/plant) and sugarcane juice @ 10 per cent (11.90 fruits/plant) (Table 11).

Next best treatment was the molasses @ 10 per cent (10.14 fruits/plant) with an increase of 15.35 and 153.50 per cent over open pollinated plot without spray and caged plot without bees, respectively. Further, it was followed by crop caged with bees (8.95 fruits/plant) and open pollinated crop without spray (8.79 fruits/plant).

The least number of fruits/plant (4.00) were recorded in the treatment caged without bees which proved to be significantly inferior to all other treatments (Table 12).

4.4.2.2 Fruit weight

The plot sprayed with cacambe (10%) recorded significantly higher fruit weight (128.10 g/fruit) which accounted for 32.88 and 84.50 per cent increase over open pollination without spray and caged plot without bees, respectively. Further Bee-Q @ 1.25 per cent (123.20 g/fruits), jaggery solution @ 10 per cent (120.80 g/fruit), sugar solution @ 10 per cent (116.80 g/fruit) and sugarcane juice @ 10 per cent (114.10 g/fruit) were equally effective and were on par with each other in fruit weight with an increased range of 18.36 to 27.80 and

64.33 to 77.44 per cent over open pollination without spray and plot caged without bees, respectively (Table 12).

4.4.2.3 Net plot yield

The open pollinated crop sprayed with cacambe (10%) recorded significantly higher net plot (5 m x 5 m) yield of 49.52 kg/plot which contributed for increase upto the tune of 93.43 and 183.29 per cent over open pollinated plot without spray and caged plot without bees, respectively. Further, it was followed by Bee-Q @ 1.25 per cent (41.85 kg/plot). However, crop sprayed with jaggery solution @ 10 per cent recorded 37.64 kg/plot of fruits which was on par with sugar solution @ 10 per cent (34.25 kg/plot), sugarcane juice @ 10 per cent (33.30 kg/plot), molasses @ 10 per cent (31.75 kg/plot) and crop caged with bees (30.96 kg/plot).

The least net plot yield of 17.48 kg/plot was obtained in the treatment caged without bees which proved to be significantly inferior to all other treatments (Table 12).

4.4.2.4 Yield / ha (converted)

The converted yield per hectare based on net plot yield followed similar trend as fruit yield of 178.10 q/ha in cacambe (10%) with per cent increase of 73.92 and 158.41 over open pollination without spray and plot caged without bees, respectively. The least yield (68.92 q/ha) was in crop caged without bees and was inferior to all the treatments (Table 12).

V. DISCUSSION

The results of the investigations carried out to know the pollinator fauna, foraging behaviour, influence of attractants in attracting the bees and effect of bee pollination on qualitative and quantitative parameters of cucumber are discussed in this chapter.

5.1 POLLINATOR FAUNA OF CUCUMBER

In the present study, total of 12 species of pollinators were recorded visiting cucumber flowers. Among the four groups of pollinators, little bee, *A. florea* was predominant constituting as high as 42.00 per cent, followed by *A. cerana* (24 per cent), *A. dorsata* (14 per cent) and others such as Lepidoptera, hymenoptera and Dipteran constituted 20 per cent. *A. florea* was maximum because many colonies were noticed in bushes nearer to research plot. The present findings are in close agreement with Prakash (2002) who reported that cucumber crop was visited by 27 insect species of which 16 belongs to Hymenoptera and four each to Diptera, Leipdoptera and Coleopteran. The Hymenoptera *viz*., *A. dorsata*, *A. cerana*, *A. florea* and *T. iridipennis* comprises more than 82 per cent of the total insect pollinators.

Kapil and Chaudhary (1974) who reported that out of total bee population, *A. florea* Fab (33.10%) was the predominant pollinator of cucurbit flowers. They also reported Halictidae and Xylocopidae also foraged on cucurbit flowers from June to September.

5.2 FORAGING ACTIVITY OF HONEY BEES ON CUCUMBER

5.2.1 Foraging activity of rock bee, *A. dorsata* on cucumber

The foraging activity of *A. dorsata* was found throughout the day from 0800 to 1800h of the day at different weeks after 10 per cent flowering.

In general, peak foraging activity of rock bee. *A. dorsata* was observed at 1200 h of the day with 6.72 bees/m²/5 min. The next maximum activity was observed at 1000 h of the day with 4.68 bees/m²/5 min. As rock bees are wild species, they can tolerate higher temperature as they might have better adaptation to weather conditions compared to other species. They construct the nests in open places on the branches of trees, walls and other parts of building.

The present results collaborate with the in finding of Jadhav (1981) who reported that *A. dorsata* was active between 1100 to 1200 h of the day. Kumar *et al*. (1994) reported that *A. dorsata* activity was peak at 0900 to 1100 h. The findings of Guruprasad (2001) on Niger, Kalmath (2002) on Onion, Mane (2003) on Coriander, Dinesh (2003) on Cucumber also gave with the present findings.

5.2.2 Foraging activity of Indian bee, *A. cerana* on cucumber

The foraging activity of *A. cerana* was observed throughout the day which started from morning 0800 h and continued upto 1800 h as well as throughout the flowering period.

The foraging activity commenced at 0800 h with an average of 4.94 bees/m²/5 min. The peak foraging activity was found at 1000 h with an average of 11.38 bees/m²/5 min and the visitation reached the lowest level during 1400 and 1800 h.

The present finding are in line with the report of Mohan Rao and Suryanarayana (1990) who reported the peak activity of *A. cerana* at 0900 h of the day in Watermelon. Guruprasad (2001) on Niger, Kalmath (2002) on Onion, Mane (2003) on Coriander also reported the maximum activity at 1200 h. Kulkarni and Dhanorkar (1998) also reported that *A. cerana* foraged for nectar from 0700 to 1530 h and for pollen from 0700 to 1500 h in Niger at Parbhani, Maharasthra. Similarly, Panda *et al.* (1995) recorded maximum bee visitation from 1100 to1200 h during the flowering period of Niger.

5.2.3 Foraging activity of little bee, *A. florea* on cucumber

The foraging activity of *A. florea* observed throughout the day during all the observation days. The foraging activity of *A. florea* commenced at 0800 h after 10 per cent flowering as they are late riser and construct comb in bushy plants.

The overall foraging activity of *A. florea* was maximum at 1200 h (15.93 bees/m²/5 min) and observed more or less uniform activity upto 1600 h. This might be due to the presence of *A. florea* colonies near to experimental field.

The present findings are in agreement with the report of Panchabhavi and Jai Rao (1978), Mohan Rao and Suryanarayana (1990) on Watermelon. Choudhary and Kumar (1998). Guruprasad (2001) on Niger, Kalmath (2002) on Onion, Mane (2003) on Coriander.

5.2.4 Foraging activity of other pollinators on cucumber

Other pollinators were found foraging on cucumber flower throughout the day during different days after flowering. The peak foraging activity of other pollinators was observed at 1000 h (6.16 pollinators/m²/5 min) after 10 per cent flowering. In general, average activity of other pollinators were maximum between 1000 and 1200 h and then gradually declined. It may be due to favourable climatic condition for more activity of pollinators. In the evening, activity declined to 3.39 pollinators/m²/5 min after 10 per cent flowering (Fig. 2).

The present findings are in line with findings of Guruprasad (2001) on Niger, Mane (2003) on Coriander and Nidagundi (2004) on Bitter gourd.

5.2.5 Comparative foraging activity of different bees and other pollinators in cucumber

The data on comparative foraging activity of different bee species and other pollinators is presented in Fig. 3.

Among different bee species, *A. florea* was the predominant on cucumber. This may be due to its preference for pollen and nectar and also close matching of its body size and flower structure.

A. florea was more active at 1200 h followed by the *A. dorsata* and *A. cerana* at 1000 h fallowed by other pollinators group. In general, activity of bees and other pollinators group was maximum between 1000 to 1200 h, which may be due to availability of pollen when peak anthesis of cucumber take place.

The maximum population of *A. dorsata*, *A. cerana* and *A. florea* was observed during mid morning hours compared to afternoon hours. This may be due to production of floral as well as extra floral nectar which become active from morning and reached maximum secretion during different hours of the day.

The present findings are in agreement with Grewal and Sidhu (1979) on Cucurbits, Mane (2003) in Coriander and Nidagundi (2004) on Bitter gourd.

5.3 EFFECTIVENESS OF DIFFERENT BEE ATTRACTANTS ON BEE VISITATION TO CUCUMBER

In the present studies, different attractants were sprayed for their efficacy in attracting the pollinators and results of the same are discussed here under.

5.3.1 Influence of attractants on visitation of *A. dorsata* on cucumber

A day before the first spray the bee activity did not differ significantly among various treatments. Cacambe @ 10 per cent (5.40 bees/m²/5 min) proved best in attracting higher number of bees on first day after the first spray. This was followed by jaggery solution @ 10 per cent (4.45 bees/m²/5 min), Bee-Q @ 1.25 per cent (3.86 bees/m²/5 min). Whereas, other treatments were inferior to above treatment and superior over control. On 3rd day after first spray, cacambe (10%) was found significantly superior over rest of the treatments. This was followed by jaggery solution (10%) and Bee-Q (1.25%) which were equally effective in attracting bees. On 5th day after first spray, cacambe (10%) attracted maximum number of bees (4.35 bees/m²/5 min), followed by jaggery solution (10%) and Bee-Q (1.25%). Whereas, remaining treatments failed to discriminate with control.

One day after second spray, cacambe @ 10 per cent (5.30 bees/m²/5 min) attracted maximum number of bees, fallowed by jaggery solution (10%) and Bee-Q (1.25%). Whereas, other treatments were found inferior to above treatments and superior over control.

On 3rd day after second spray, once again cacambe (10%) proved to be superior over rest of the treatments by recording maximum number of bees (6.00 bees/m²/5 min). The next best treatments was jaggery solution (10%) and molasses (10%) on par with each other and above treatments were superior over control.

On 5th day after second spray, cacambe (10%) found significantly superior over jaggery solution (10%), Bee-Q (1.25%), sugarcane juice (10%) and sugar solution (10%). Whereas, untreated control found inferior to above treatments and attracted least number of bees (1.80 bees/m²/5 min).

First day after 3rd spray, cacambe attracted maximum number of bees (5.98 bees/m²/5 min) which was fallowed by jaggery solution (4.50 bees/m²/5 min). On third day, again cacambe (6.25 bees/m²/5 min) proved superior in attracting more bees over the other treatments, followed by jaggery solution, Bee-Q and sugarcane juice. Similar trend was noticed with respect to third spray, on 5th day after third spray, cacambe, jaggery solution, Bee-Q and sugarcane juice attracted more number of bees with range of 2.80 to 5.35 bees/m²/5 min. These were equally effective in attracting of bees.

The present results are in close agreement with the report of Kalmath (2002) on Onion. Further, results obtained on the efficacy of Bee-Q and sugar solution endorse the earlier reports of Viraktamath and Anagoudar (2002), Viraktamath and Patil (1999), Patil (1999), Murasing (2000), Guruprasad (2001), Dinesh (2003) on Cucumber and Nidagundi (2004) on Bittergourd upto 5th day after spray.

5.3.2 Influence of attractants on visitation of *A. cerana* on cucumber

A day before the first spray, bee visits were significantly on par with each other in different treatments. However, on first day after first spray, cacambe @ 10 per cent (8.86 bees/m²/5 min) attracted maximum number of bees, which was on par with Bee-Q @ 1.25 per cent (8.48 bees/m²/5 min), followed by jaggery solution @ 10 per cent (8.25 bees/m²/5 min). Whereas, untreated control was found inferior to all the treatments.

On 3rd day after first spray, cacambe (10%) found to be superior over rest of the treatment as it attracted maximum of 12.68 bees/m²/5 min fallowed by Bee-Q (1.25%) and jaggery solution (10%). However, sugar solution @ 10 per cent (7.00 bees/m²/5 min) was on par with sugarcane juice @ 10 per cent (7.85 bees/m²/5 min). Whereas, least number of bees were attracted by untreated control (5.00 bees/m²/5 min).

On 5th day after first spray, cacambe (10%), jaggery solution (10%) and Bee-Q (1.25%) were significantly superior over rest of the treatments. Whereas, sugarcane juice (10%) and sugar solution (10%) followed the above treatments and molasses (10%) was superior over untreated control.

A day after second spray, cacambe @ 10 per cent (13.85 bees/m²/5 min) attracted higher number of bee and found to be superior over Bee-Q (1.25) and jaggery solution (10%), followed by sugarcane juice (10%) which were on par with molasses (10%) and sugar solution (10%).

On 3rd day after second spray, cacambe (10%), Bee-Q (1.25%) and jaggery solution (10%) were found to be effective with attraction maximum number of bees which ranged from 11.26 to 19.03 bees/m²/5 min), followed by sugarcane juice (10%) which was on par with sugar solution (10%).

On 5th day after second spray, cacambe (10%), Bee-Q (1.25%) and jaggery solution (10%) were found to be equally effective and significantly superior over other treatments. Whereas, least number of bees were attracted by untreated control (6.25 bees/m²/5 min).

First day after third spray, cacambe attracted maximum number of bees (17 bees/m²/5 min) which was followed by Bee-Q 1.25 per cent (14.33 bees/m²/5 min). On third day, again cacambe (18.14 bees/m²/5 min) proved superior in attracting more bees over the other treatments, followed by Bee-Q and jaggery solution. Similar trend was noticed on 5th day after third spray where in cacambe, Bee-Q and jaggery solution attracted more number of bees that ranged from 11.00 to 15.05 bees/m²/5 min). These were equally effective in attracting of bees.

The attractiveness of cacambe to *A. cerana* collaborated with the findings of Kalmath (2002) on Onion, Dinesh (2003) on Cucumber, Nidagundi (2004) on Bitter gourd, Shankarmurthi (2004) on Ridge gourd and Chandrashekar (2005) on Radish. The attractiveness of Bee-Q and sugar solution was in line with the finding of Viraktamath and Anagoudar (2002) on Cucumber and Guruprasad (2001) on Niger upto 5th day after spray.

5.3.3 Influence of attractants on visitation of *A. florea* on cucumber

One day before the first spray (at 10% flowering), the bee activity did not differ significantly among various treatments. Cacambe @ 10 per cent (4.50 bees/m²/5 min) proved best in attracting higher number of bees on first day after the spray. This was followed by Bee-Q @ 1.25 per cent (3.65 bees/m²/5 min), jaggery solution @ 10 per cent (3.00 bees/m²/5 min). Whereas, other treatments were inferior to above treatments but superior over control.

On 3rd day after first spray, cacambe @ 10 per cent (5.00 bees/m²/5 min) attracted more number of bees which was followed by Bee-Qs @ 1.25 per cent and sugar solution @ 10 per cent. However, other treatments remained less effective except jaggery solution @ 10 per cent which attracted more number of bees than molasses @ 10 per cent and control.

On 5th day after first spray, cacambe (10%) and Bee-Q (1.25%) were found to be successful in maintaining higher efficacy in attracting more bees (4.10 and 3.66 bees/m²/5 min, respectively). The remaining treatments viz. jaggery solution (10%), sugar solution (10%) and sugarcane juice (10%) were found less effective, but superior over control.

A day after second spray, cacambe @ 10 per cent (4.65 bees/m²/5 min) attracted maximum number of bees followed by Bee-Q (1.25%), jaggery solution (10%), sugar solution (10%) and sugarcane juice (10%). The above treatments including molasses (10%) were found effective over control.

On 3rd day after second spray, cacambe (10%) found to be effective in attracting higher number of bees (5.50 bees/m²/5 min). The next best treatment was Bee-Q @ 1.25 per cent (4.00 bees/m²/5 min) which was on par with jaggery solution (10%), sugar solution (10%) and sugarcane juice (10%). However, molasses (10%) was significantly superior over control.

On 5th day after second spray, cacambe (10%), jaggery solution (10%) and Bee-Q (1.25%) were found to be significantly superior over rest of treatments. Whereas, remaining treatments were found to be superior in attracting higher number of bees over control.

One day after 3rd spray, cacambe (10%) proved to be very effective in attracting more number of bees (4.85 bees/m²/5 min). The next best treatments were Bee-Q (1.25%) and jaggery solution (10%). Other treatments failed to attract more number of bees, but significantly superior over control.

On 3rd day after third spray, cacambe @ 10 per cent attracted higher number of bees (5.40 bees/m²/5 min), followed by Bee-Q @ 1.25 percent (4.55 bees/m²/5 min). The next best treatment was jaggery solution @ 10 per cent which was on par with sugar solution 10 per cent. Remaining treatment failed to attract more number of bees.

On 5th day after 3rd spray, once again cacambe (10%) was significantly superior over other treatment, followed by Bee-Q (1.25%). The remaining treatment was inferior to above treatments but superior over open pollination without spray.

The attractiveness of cacambe to *A. florea* confirms the earlier reports of Kalmath (2002) on Onion and the attractiveness of Bee-Q and sugar solution was in agreement with the reports of Guruprasad (2001) on Niger, Patil (1999) on Sesamum. Murasing (2000) on Mustard, Dinesh (2003) on Cucumber, Shankarmurthy (2004) on Ridgegourd and Nidagundi (2004) on Bittergourd.

5.3.4 Influence of attractants on visitation of other pollinators on cucumber

A day before first spray (10% flowering), there was no significant difference in visitation of other pollinators among various treatments. However, one day after first spray, cacambe @ 10 per cent (1.57 pollinators/m²/5 min) was found to be significantly superior over other treatment which was on par with jaggery solution @ 10 per cent. Whereas, other treatments was found to be effective over control. On 3rd day after first spray, cacambe (10%) was found to superior over other treatments, followed by Bee-Q (1.25%) and jaggery solution (10%). However, sugar solution (10%) on par with sugarcane juice (10%). On 5th day after first spray, cacambe (10%), jaggery solution (10%) and Bee-Q (1.25%) were found to be significantly superior in attracting higher number of other pollinators. Whereas, other treatments except untreated control were found to be equally effective, but inferior to earlier treatment.

On the first day after second spray, cacambe @ 10 per cent (3.16 pollinators/m²/5 min) attracted significantly higher number of other pollinators which was on par with jaggery solution (10%) followed by Bee-Q (1.25%). However, other treatments were found to be superior over untreated control and inferior to above treatments.

On 3rd day after second spray, cacambe (10%), Bee-Q (1.25%) and jaggery solution (10%) were found to be effective in attracting maximum number of other pollinators (3.40 to 4.37 pollinators/m²/5 min) followed by sugarcane juice (10%) and sugar solution (10%). Whereas, untreated control found to be inferior among all the treatments with 1.40 pollinators/m²/5 min.

On the 5th day after second spray, cacambe (10%), Bee-Q (1.25%) and jaggery solution (10%) found to be superior which attracted other pollinators ranging from 2.36 to 3.10 pollinators/m²/5 min. However, other treatments were found inferior to the above treatments and superior over control. The untreated control recorded 1.38 pollinators/m²/5 min.

First day after 3rd spray, cacambe (10%) attract more number of pollinators 4.85 pollinators/m²/5 min followed by Bee-Q (1.25%) and jaggery solution (10%). Same trend was also noticed in 3rd and 5th day after 3rd spray.

Present findings are in close agreement with Patil (1999) on Sesamum, Murasing (2000) on Mustard, Guruprasad (2001) on Niger, Kalmath (2002) on Onion, Dinesh (2003) in Cucumber, Shankermurthy (2004) on Ridge gourd and Nidagundi (2004) on Bittergourd who reported that use of Bee-Q and sugar solution do attract other pollinators in more numbers.

The increased bee visitation has been observed on crops sprayed with attractants in Apple and Pear (Currie *et al*., 1992b), Berry (Currie *et al*., 1992a), Watermelon (Elmstrom and Maynard, 1991 and Sattigi *et al*., 2001a), Apple and Pulm (Mayer *et al*., 1989a and b), Cranberry (Mackenzie and Averill, 1992), Raspberry (Niera and Barrige, 1995). These reports confirms the present findings that attractants increases the visitation of insects to flowers.

5.4 INFLUENCE OF BEE POLLINATION ON QUALITATIVE AND QUANTITATIVE PARAMETERS OF CUCUMBER

5.4.1 Influence on qualitative parameters

5.4.1.1 Number of Male and Female flowers per plant

The effect of attractants in producing more number of male and female flowers was not apparent, as all the treatments failed to produce significantly more number of male and female flowers per plant than the unsprayed crop or caged crop without bees. These results clearly indicated that number of male and female flowers per plant is genetically controlled but not influenced by external factors.

These results endorse the earlier reports of Viraktamath and Patil (1999) on Sesamum and Guruprasad (2001) on Niger. They reported that there was non-significant effects of attractants on number of heads per plant when compared to open pollination but obtained significantly higher pods per plants when compared to caged crop.

5.4.1.2 Per cent fruit set

The open pollinated crop which received cacambe (10%) recorded significantly higher per cent fruit set (94.66%) because of more number of bee visits per unit time which accounted for maximum of 115.52 and 308.36 per cent increase over open pollinated crop without spray and crop caged without bees, respectively. Whereas, sugar solution (10%), Bee-Q (1.25%) and jaggery solution (10%) were the next best treatments and were on par with each other and significantly superior over rest of the treatments. However, caged crops without bees recorded significantly lowest fruit set of 23.18 per cent. This study clearly indicates that pollinators are must for higher fruit set in cucumber.

The present findings are in line with the reports of Kalmath (2002) where plot caged without bees recorded 98.33 chaffy seeds per umbel in Onion and Dinesh (2003) where plot caged without bees recorded maximum number of dropped fruits per plant (6.81 fruits/plant) in Cucumber.

5.4.1.3 Healthy fruits per plant

Open pollinated plot which received cacambe @ 10 per cent (17.22/healthy fruits/plant) recorded maximum number of healthy fruits/ which followed by jaggery solution (10%) and Bee-Q (1.25%) with 11.25 and 10.19 healthy fruits/plant and were on par with each other. Next best treatments were sugar solution (10%), sugarcane juice (10%) and molasses (10%). Whereas, no healthy fruits were found to crop caged without bees.

The present finding are in line with the reports of Prasad *et al.* (1989) also reported that open pollinated Radish plot had the maximum number of good seed per siliqua.

5.4.1.4 Malformed fruits per plant

The crop with open pollination recorded 5.79 malformed fruit per plant fallowed by crop sprayed with molasses @ 10 per cent (5.03 malformed fruit/plant) and suger cane juice @ 10 per cent (5.00 malformed fruit/plant). Whereas, crop caged without bees recorded 4.00 malformed fruit/plant but no healthy fruit per plant were recorded.

The present findings are in line with the reports of Bisht *et al.* (1983) who reported that plants caged to excluded insects yielded less number of seeds per pod in Radish.

5.4.1.5 Length of fruits

Length of the fruit was maximum in cacambe (10%) sprayed plot (22.00 cm) which accounted for increase of 43.79 and 62.96 per cent in length of fruit over open pollination without spray and caged without bees, respectively. This was followed by Bee-Q (1.25%) and jaggery solution (10%).

The present findings are in close agreement with Bevacqua (1999) and, Mussen and Thorp (1995) on Cucurbits who reported that good pollination results in uniform and good fruits.

5.4.1.6 Diameter of fruit

The cacambe (10%) sprayed plot produced maximum fruits with greater circumference *i.e.* interms of diameter of the fruits (5.70 cm) which resulted in 42.50 and 46.15 per cent increase over open pollination without any spray and caged plot without bees, respectively. However, jaggery solution @ 10 per cent (5.50 cm) and Bee-Q @ 1.25 per cent (5.00 cm) were next best treatments.

The present findings are in line with the reports (Anonymous, 1996) who opined that proper pollination and receipt of eight or more bee visits by a female flower is necessary for good yield. Inadequate pollination results in shrivel, often turn black colour and finally abort. This also lead to no increase in size of fruits. Mussen and Thorp (1995) on Cucurbits reported that better pollination results in uniform sized fruits.

5.4.2 Influence on quantitative parameters

5.4.2.1 Number of fruits per plant

The crop sprayed with cacambe (10%) produced significantly higher number of fruits per plant (19.00), which accounted for 116.15 and 375.00 per cent increase over open pollinated crop without spray and caged crop without bees, respectively. Further it was followed by jaggery solution (10%), Bee-Q (1.25%) and sugar solution (10%).

These results are clearly indicated that application of attractants had positive effect in increasing the number of fruit set per plant which was due to increased visitation of bees resulting in effective cross pollination by entomophylly.

These findings corroborate the results of Kalmath (2002) on Onion, Sattigi *et al.* (2001b) and Guruprasad (2001) on Niger, Viraktamath and Patil (1999), Murasing (2000) on Mustard, Elmstrom and Maynard (1991) and Lingappa *et al.* (1999) on Watermelon, Schultheis *et al.* (1994) and Viraktamath and Anagoudar (2002) and Dinesh (2003) on Cucumber.

5.4.2.2 Weight of fruit

The open pollinated crop sprayed with cacambe (10%) produced significantly higher fruit weight (128.10 g/fruit) which accounted for 32.88 and 84.50 per cent increase over open pollination without spray and caged without bees, respectively. Further, Bee-Q (1.25%), jaggery solution (10%) and sugar solution (10%) recorded fruit weight ranging from 116.8 to 123.2 g/fruit. The fruit weight was minimum with 69.43 in the crop caged without bees which proved significantly inferior to above treatments.

5.4.2.3 Net plot yield

Net plot (5 m x 5 m) yield which ranged from 34.25 to 49.52 kg was obtained in the crop sprayed with cacambe (10%), Bee-Q (1.25%), jaggery solution (10%) and sugar solution (10%) as against 25.60 and 17.48 kg in open pollination without any spray and crop caged without bees, respectively. Thus, resulted in increase of 33.78 to 93.43 and 95.93 to 183.29 per cent over open pollination without any spray and crop caged without bees, respectively

The remaining treatments produced comparatively more net plot yield as compared with crop caged without bees but not with open pollinated without any spray.

These results revealed that application of attractants could increase the yield due to increased activity of the pollinators. The higher efficiency of cacambe (10%) in producing the more yield could be attributed to the component present in queen madibular pheromone.

The present findings in respect to bee attractants endrose the earlier reports of Elmstrom and Maynard *et al.* (1992), Schltheis *et al.* (1994), Viraktamath and Anagoudar (2002) on Cucumber, Kalmath (2002) on Onion, Sattigi *et al.* (2001b) and Guruprasad (2001) who reported significantly higher seed yield in Niger due to application of Bee-Q (1.25%). Similar results of increased seed yield in Sesamum have been reported by Viraktamath and Patil (1999).

5.4.2.4 Yield/ha (converted)

The converted yield per hectare based on net plot yield followed similar trend with is maximum of 178.10 q/ha in cacambe (10%) with per cent increase of 73.92 and 158.41 over open pollination without any spray and plot caged without bees, respectively. The lowest yield of 68.92 q/ha was recorded in crop caged without bees which was inferior to all the treatments.

The present finding with respect to bee attractants endrose the earlier reports of Viraktamath and Anagoudar (2002) and Dinesh (2003) on Cucumber.

The present findings are in close agreement with the reports of Sundar (1978), Mohan Rao and Suryanarayana (1988) and Sattigi *et al.* (2001a) on Watermelon, Kauffeld *et al.* (1975), Rafiq Ahmed (1992), Viraktamath and Anagoudar (2002) and Dinesh (2003) on Cucumber, Kalmath (2002) on Onion, Guruprasad (2001) on Niger.

VI. SUMMARY

Results of the investigations carried out during *rabi* season of 2004-05 at Mangalagatti village which is located 10 km away from Main Agricultural Research Station, Dharwad on pollinator fauna, foraging behaviour of bees, effectiveness of attractants in attracting bees and its effect on qualitative and quantitative parameters of cucumber are summarized below.

Totally 12 species of pollinators were recorded visiting the flowers of cucumber. Of these, 9 species belonged to Hymenoptera, comprising, 75.00 per cent of total pollinators and 1 species of Lepidoptera and 2 species of Diptera. Among the pollinators, *A. florea* was the most predominant species constituting 42.00 per cent of the total pollinators followed by *A. cerana* (24%), *A. dorsata* (14%) and other pollinators (20%).

Activity of *A. dorsata* started at 0800 h and gradually increased attaining a peak at 1200 h. Foraging activity of *A. cerana* was observed from 0800 h which reached the peak at 1000 h. *A. florea* foraging was maximum at 1000 to 1200 h. Activity of other pollinators was noticed throughout the day, however peak activity was observed at 1000 h.

Spraying cacambe (10%) attracted more *A. dorsata* upto 5th day after first, second and third spray. Jaggery (10%) and Bee-Q (1.25%) were the next best treatments. While, sugarcane juice (10%), sugar solution (10%) and molasses (10%) attracted less bees.

Spraying of cacambe (10%) recorded maximum number of *A. cerana* upto 5th day of I, II and III spray, followed by Bee-Q (1.25%) and jaggery solution (10%). Sugarcane juice (10%) and sugar solution were also effective but molasses (10%) fail to attract more bees.

Treatments with cacambe (10%), Bee-Q (1.25%) and jaggery solution (10%) were effective in attracting more *A. florea* upto 5th day after 1st, 2nd and 3rd spray, sugar solution (10%) and sugarcane juice (10%) were the next best treatments.

Similarly, cacambe (10%) attracted maximum number of other pollinators after 1st, 2nd and 3rd spray followed Bee-Q (1.25%) and jaggery solution (10%). Sugarcane juice (10%) and sugar solution (10%) were next best treatments and Molasses (10%) failed to attract other pollinators.

Spraying of cacambe (10%), Bee-Q (1.25%) and jaggery solution (10%) were significantly superior in enhancing productivity of cucumber. The number of flowers per plant did not vary significantly with spray of any treatment. The number of fruits per plant was highest (19.00) in the treatment with cacambe (10%) as against 8.79 and 4.00 fruits per plant in open pollination without any spray and caged plot without bees, respectively. This resulted in increase of 116.15 and 375.00 per cent over open pollination fruit set 94.66 per cent were found in the treatment with cacambe (10%) as against 43.92 per and 23.18 in open pollination without spray and caged plot without bees, respectively. Maximum healthy fruits per plant of 17.22 were found in the treatment with cacambe (10%) as against 3.00 and 0.00 fruits per plant over open pollination without any spray and crop caged without bees, respectively. Minimum malformed fruits per plant (1.78) were found in the treatment with cacambe (10%) as against 5.79 and 4.00 fruits per plant in open pollination without any spray and crop caged without bees, respectively. Highest fruit weight of 128.10 g was recorded in treatment sprayed with cacambe (10%) as against 96.40 and 63.43 g in open pollination without any spray and plot caged without bees, respectively. Length of the fruit was highest (22.00 cm) in the treatment with cacambe as against 17.00 and 13.50 cm in open pollination without spray and caged plot without bees, respectively. Highest fruit diameter of 5.70 cm was recorded in treatment sprayed with cacambe (10%) as against 4.00 and 3.90 cm fruit diameter in open pollination without spray and caged plot without bees, respectively.

The crop sprayed with cacambe (10%) recorded highest plot yield of 49.52 kg as against 25.60 and 17.48 kg per plot in open pollination without any spray and caged plot without bees, respectively. Thus, it accounted for 93.43 and 183.29 per cent increased over open pollination without any spray and caged plot without bees, respectively.

The crop sprayed with cacambe (10%) recorded highest yield (converted) of 178.10 q/ha as against 102.40 and 68.92 q/ha as in open pollination without any spray and caged plot without any bees, respectively.

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IMPACT OF HONEYBEE POLLINATION ON QUALITATIVE AND QUANTITATIVE PARAMETERS OF CUCUMBER (*Cucumis sativa* L.)

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ABSTRACT

Studies were made on pollinator fauna of cucumber foraging behaviour of bees in cucumber, effectiveness of different bees attractants in attracting the bees cucumber and influence of bee pollination on qualitative and quantitative parameters of cucumber at Mangalagatti village nearer to Main Agricultural Research Station, Dharwad during *rabi* season 2005-06.

Among 12 species of pollinators, *Apis florae* F. was the most predominant constituting 42 per cent of the total pollinators followed by *A. cerana*, *A. dorsata* and other pollinators. Peak foraging activity of all the pollinators was observed at 1200 h of the day, while foraging activity was minimum during 1400 and 1800 h of the day.

Spraying of cacambe (10%), Bee-Q (1.25%) and jaggery solution (10%) were significantly superior in enhancing productivity of cucumber. The number of flowers per plant did not vary significantly with spray of any treatment. The number of fruits per plant was highest (19.00) in the treatment with cacambe (10%) as against 8.79 and 4.00 fruits per plant in open pollination without any spray and caged plot without bees, respectively. Maximum healthy fruits per plant of 17.22 and minimum malformed fruits per plant (1.78) were found in the treatment with cacambe (10%). Highest fruit weight of 128.10 g was recorded in treatment sprayed with cacambe (10%) as against 96.40 and 63.43 g in open pollination without any spray and plot caged without bees, respectively. Length of the fruit was highest (22.00 cm) in the treatment with cacambe as against 17.00 and 13.50 cm in open pollination without spray and caged plot without bees, respectively. Highest fruit diameter of 5.70 cm was recorded in treatment sprayed with cacambe (10%) as against 4.00 and 3.90 cm fruit diameter in open pollination without spray and caged plot without bees, respectively.