STUDIES ON ROLE OF HONEY BEES AS A POLLINATORS ON SEED PRODUCTION OF BITTER GOURD (*Momordica charantia* L.)''

By

Mr. MANCHARE RAVINDRA RAOSAHEB
(Reg. No. 016/148)

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413 722, DIST. AHMEDNAGAR,
MAHARASHTRA, INDIA
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A Thesis submitted to the
MAHATMA PHULE KRISHI VIDYAPEETH,
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MAHARASHTRA, INDIA.

In partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

In

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MAHARASHTRA (INDIA)

2018

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part
there of has not been submitted
by me or other person to any
other University or Institute
for a Degree or
Diploma

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Maharashtra State (India)

CERTIFICATE

This is to certify that the thesis entitled **"Studies on role of honey bees as a pollinators on seed production of bitter gourd (*Momordica charantia* L.)"** submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY,** embodies the result of a piece of bonafide research work carried out by **Mr. MANCHARE RAVINDRA RAOSAHEB** under my guidance and supervision and that no part of the thesis has been submitted to any other University for Degree or Diploma.

The assistance and help rendered during the course of this investigation have been duly acknowledged.

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Date: / /2018

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LIST OF ABBREVIATIONS

Am	:	Anti meridian
Cm	:	Centimetre (s)
CD	:	Critical difference
cv.	:	Cultivar (s)
DAS	:	Days after spraying
DBS	:	Days before spraying
e.g.	:	Exampligrantia (for example)
et al.	:	*et alii* (and others)
etc.	:	exceteras (so on)
Fig.	:	Figure
G	:	Gram (s)
Hr	:	Hour (s)
Ha	:	Hectare (s)
i.e.	:	id est (that is)
Kg	:	Kilogram (s)
Lit	:	Litre (s)
M	:	Meter (s)
max.	:	Maximum
min.	:	Minute
NS	:	Non-significant
No.	:	Number
N	:	North
OP	:	Open pollination
pm	:	Post meridian
pp.	:	Pertaining pages
PWI	:	Pollination without insect
RH	:	Relative humidity
SE	:	Standard error
T	:	Tonne
Vs	:	Verses
viz.,	:	Videlicet (namely)
/	:	Per
%	:	Per cent
^{0}C	:	Degree Centigrade (Celsius)

ABSTRACT

"STUDIES ON ROLE OF HONEY BEES AS A POLLINATORS ON SEED PRODUCTION OF BITTER GOURD (*Momardica charantia* L.)"

By

MR. MANCHARE RAVINDRA RAOSAHEB

A candidate for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL ENTOMOLOGY

Mahatma Phule Krishi Vidyapeeth, Rahuri - 413 722

2018

Research Guide	**:**	**Dr. S. R. Kulkarni**
Department	**:**	**Agricultural Entomology**

An experiment entitled "Studies on role of honey bees as a pollinators in seed production of bitter gourd (*Momordica charantia* L.)" was conducted at the seed production plot of All India Coordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, during *Rabi* 2016. The experiment was laid out in randomized block design with nine treatments and three replications with view to find out the effect of bee attractants on activities of honey bees and effect of honey bee visits on seed yield and yield contributing characters of bitter gourd. The bee attractants were sprayed two times, first at 10 per cent flowering and second at 50 per cent flowering.

The results from the foraging activity of bees noted that the intensity of *Apis dorsata, Apis cerana indica and A. mellifera* were reached at its peak at between 10:00 to 12:00 hrs. At the same time, *Apis cerena indica* was proved to be efficient pollinator because it visits more number of flowers per minute and it was followed by *Apis dorsata* and *Apis mellifera.*

Spraying of bee attractants *i. e.* honey solution 10 percent, jaggery solution 10 per cent and molasses 10 per cent attracted the maximum number of *A. cerena indica* up to 5th day after first and 7th day after second spray. Whereas, in case of *A. dorsata and A. mellifera* similar trend was observed after first spray and second spray of bee attractants.

Abstract continue…….. **R. R. Manchare**

The yield contributing characters were influenced by various sprays of bee attractant treatments. The highest number of fruits/plant(35.88) and the highest number of seeds/fruit (41.4) was recorded in the treatment of honey solution 10 per cent which resulted in increase of yield by 30.59 and 53.33 per cent over open pollination without spray and pollination without insects, respectively. The lowest per cent of wrinkled seeds/fruit (1.20 %) was found with the treatment of honey solution 10 per cent followed by jaggery solution 10 per cent (1.86 %).

The highest weight of 100 seeds (29.57 g) was recorded with honey solution 10 per cent followed by 27.20 g in jaggery solution 10 per cent as against open pollination without spray and pollination without insects (25.96 and 24.50 g respectively). The crop sprayed with honey solution 10 per cent recorded highest seed yield of 2.19 kg/5 plants as against open pollination without spray (1.24 kg/5 plants) and pollination without insects (0.52 kg/5 plants).

The highest seed yield per hectare (4.818 q/ha) was recorded with honey solution 10 per cent as against open pollination without spray (2.728 q/ha) and pollination without insects (1.144 q/ha) and it was followed by jaggery solution 10 per cent (3.828 q/ha), molasses 10 per cent (3.564 q/ha) and sugarcane juice 10 per cent (3.344 q/ha).

1. INTRODUCTION

Among the all cucurbits cultivated in India, bitter gourd (*Momordica charantia* L.) is one of the most important vegetable crop belonging from cucurbitaceae family. It is considered to be an old world species with its native home being the tropical Africa and Asia. It is widely distributed in Asia, Africa, China, Malaysia, Caribbean countries and Tropical Africa. (Bailey 1949). Also it is grown as ornamental crop in USA, UK and France. The Bitter gourd fruits contain 83-92 g moisture, 1.5-2.0 g protein, 4-10.5 gm carbohydrates, 0.8-1.7 gm fibers, 20-23 mg calcium, 38-70 mg phosphorous, 1.8-2.0 mg iron, 88-96 mg vitamin C, energy value 105-250 KJ per 100 g edible portion. Also antioxidant in fruit 19 micro mg/gm (very low).

It is cultivated throughout India and is also found growing as a wild crop in many parts of the country. It is grown in West Bengal, Maharashtra and Orissa majorly. The Area of Bitter gourd in India is 98.00 thousand hectare and production is about 1106.00 thousand MT (Anonymous, 2016).

Odisha is the leading state to cultivate bitter gourd with area of 11.06 thousand hectare but as per production is concern Chhattisgarh is leading state with production of 123.70 thousand MT in India followed by Odisha, Madhya Pradesh, Andhra Pradesh, Bihar and Telangana. Maharashtra has 0.87 thousand hectares area while production is 15.99 thousands MT. (Anonymous, 2015).

Flowering phenology of cucurbitaceous crops ensures the cross pollination for better fruit set and yield. Their flowers are usually monoecious i.e. they produce male and female flowers separately on the same plant but at different internodes. The male to female flower ratio is about 25:1. Long days cause male flowers to bloom up to two weeks before female flowers (Palada and Chang, 2003). In bitter gourd cross pollination ranges from 80-100 per cent. Anthesis takes place between 03:30 and 07:30 and stigma remains receptive from 24 hrs before to 24 hrs after anthesis and most receptive during early hours of the day (Deshpande *et al*., 1979).

The open position of the flowers in bitter gourd makes them easy for the pollinators to access and exploit floral rewards. The high male to female ratio achieves the production of sufficient amount of pollen deposits, thus results in effective pollination. A successfully pollinated flower starts to develop fruit on the second to fifth day after it had opened with petals detached, un-pollinated flowers dry up and the ovary become yellow on fifth day (Deyto and Cervancia, 2009). Hence, pollination is largely dependent on various pollinating agents, Insect pollinators play a crucial role in effecting optimum pollination including especially by honey bees. Insects are required for pollen transfer because of the large sized pollen grains, their stickiness, the way they

are released from the anthers and thus contributing to both increased production in quantity and quality. (Lauria and Fred, 1995).

The insects from Apidae family are the most reliable agents for pollination. Among members of Apidae family, honey bees are particularly important pollinators as they are capable of carrying pollen and in the process, the plants visited by them are benefited (Tewari and Singh, 1983). The pollination is entomophilous and bees mostly *Apis florea* F. , *Apis cerana* F, *Apis dorsata* F., *Nomiodes spp, Halictine spp* are main pollinating against and beetles like *Conpophilus spp*, moths like *Planidia spp* and *Pygargonia sp*. and various species of birds are minor ones.

Among them *A. mellifera* and *A. cerena indica* is having the great impact in pollination as compared to other pollinating agent with multiple combs and artificially reared are observed in European countries. In comparison with Italian bees (*A. mellifera*), some studies on pollination through Stingless bees (*Trigona irridipenis*) has been carried out in India and other countries like Kenya and Philippines.

Bitter gourd seed yield is heavily depends on bee pollinators; for efficient pollination in highly cross pollinated crop honey bees are most important. Bees are most efficient and reliable pollinators in increasing crop productivity in quantity and quality of seeds because of their characteristics of flower fidelity, thoroughness with all essential organ of flower, long working duration, large number of population, their social organization, method of communication and morphological adaptations. All these qualities are not found in any other insect other than honey bees. Among all pollinators honey bees are predominant and best pollinators.

Adequate pollination is vital for any significant increase in production, about 90 per cent cross pollination is carried out by the insects out of total pollination in bitter gourd, 85 per cent of which comprises by bees. Honey bees are efficient and primary pollinators of entomophilous crop like most of vegetable crops. Pollination is one of the important natural factors enhancing crop yield. Utilization of pollinators especially honey bee to be considered as one of the cheapest, eco-friendly, natural but totally neglected and unexploited input which maximize the yield of cross pollinated.

The material to increase the honey bee visit to specific crops would be of great practical value to harvest the benefits of cross pollination. Commercial and local bee attractants *viz.*, Bee line, Bee here, Bee scent, Bee scent plus, fruit boost, Bee-Q, Sugar solution, Sugarcane juice, Jaggery solution, Molasses, etc. are being used to boost the yield of pea, peach, blue berries, watermelon and apple in the United States, Spain and Canada. However, in India, the meagre studies on the use of bee attractants were noticed. Further, though some studies have been made on pollination of bitter gourd but no attempts have been made for exploring the possible use of bee attractants to boost productivity of bitter gourd in India. The conservation and management of

insect pollinators is gaining importance day by day for which studies on pollinators' diversity, species richness and abundance are essential. Hence, the present investigations have been taken up to generate information about the following objectives are taken for study:

i. To study the effect of bee attractant on activity of bees in bitter gourd.
ii. To study the effect of honeybees on seed yield and yield contributing characters of bitter gourd.

2. REVIEW OF LITERATURE

For the study of effect of bee attractants on activities on bees and effect on seed yield and yield contributing characters in bitter gourd following articles were referred. The referred articles summery have given below:

2.1. Effect of bee attractant on bee activity on bitter gourd

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

Williams *et al.* (1981) observed 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.

Allsopp and Cherry (1991) reported that 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 fatty acids did not attract the bees.

Looper and Rossette (1991) studied by conducting field trials on two adjacent fields of *Citrullus lanatus* L. in Arizona, USA, in which honey bees were introduced at a stocking density of two colonies per acre. Bee scent was sprayed over alternate eighteen row strips in one field and the other field was untreated.

Ortiz-Sanchoz (1993) observed that the efficacy of Bee-here 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 with concentration 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.

Schultheis *et al.* (1994) evaluated two commercial bee attractants like Bee scent and Bee line on cucumber and watermelon. They found that these attractants increased the yield and also bee visitation.

Ambrose *et al.* (1995) observed that 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 did not increase the bee activity on vine crop when compared to untreated control and not they increase the value of subsequent harvest.

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

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 two times on watermelon. Whereas in safflower, the seed yield was significantly increased to the extent of 54.84 per cent over the control.

Patil (1999) observed that spraying of Bee-Q on sesamum increase bee visitation in Dharwad.

Tim A. Heard (1999) reported from twenty crops, the strengths and limitations of stingless bees as crop pollinators are discussed. Aspects of their biology that impact on their potential for crop pollination are reviewed, including generalized flower visiting behavior of colonies, floral constancy of individual bees, flight range, and the importance of natural vegetation for maintaining natural populations.

Patil *et al.* (2000) studied that spraying of Bee-Q and Bee here on sesamum increased bee visitation and yield parameters significantly on sprayed crop up to 5th day in Dharwad.

Viraktamath and Anagoudar (2002) observed that 2 applications of Bee-Q (12.5 gm/lit), Bee-here (4 ml/lit) and sugar solution (10 %) on staminate flowers of *Cucumis sativa* enticed more number of bees (4.01 to 4.97 bees/flower in 5 min.) up to 5 days after first and second sprays compared to unsprayed crop (3.25 to 3.59 bees). Similarly, higher visitations were recorded on pistillate flowers on the sprayed crop.

Malerbo-Souza *et al.* (2004) observed that Bee-Here, eugenol, geraniol, citral, and lemon grass extract, mainly diluted in water, were effective in attracting honeybees to orchards. However, these compounds were less effective when diluted in sugar syrup and also proved the most frequent visitor to the flowers was *Apis mellifera* (Africanized). Flowers visited less than 10 times showed low fructification.

Nidagundi (2004) observed 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 pollinators.

Naik *et al.* (2005) showed that leaf extract of the plant *Swertia densifolia* possess attractant and repellent properties towards honey bees, *Apis cerana indica*. Formulations in liquid paraffin of lower concentrations were repellent, whereas those with higher concentrations were found to be attractant.

Nithya *et al.* (2012) showed that the efficiency of Citral E, Citral Z, F. *budrunga*, S. *densifolia* at par with the commercial bee attractant Fruit boost in enticing more pollinators in sesame and observed that indigenous plant based attractants are the alternate options to the commercial bee attractants.

Venkataramegowda Sivaram *et al.* (2013) showed that use of bee attractants, Bee-Q and Fruit Boost in the pollination of niger. Bee visitations to niger flowers were observed for two weeks and an estimation of seed yield was determined. Results indicate that applications of Bee-Q at 12.5 gm/lit and Fruit boost at 0.75 ml/lit on niger plots significantly increased the number of bee foragers over control plots. In addition, plots sprayed with these bee attractants significantly enhanced the seed set, seed weight, and germination of niger.

Naik *et al.* (2014) observed that bee attractants play a beneficial role in enhancing pollination and yield of crops especially when target crop is not so attractive to the bees naturally or when the weather conditions are not conducive for foraging by the bees on target crop and evaluated that Citral E, Citral Z, F. budrunga, S. densifolia attracted significantly more number of bees with 2.13 to 2.96 bees /10m^2/5 min. Which were on par with each other and were as good as Fruit boost showed 2.00 to 2.17 bees /10m^2/5 min.

Jayaramappa and Bhargava (2015) observed that the usage of bee attractants, Bee-Q and Fruit Boost in the pollination of watermelon at different concentrations and indicated that, Bee-Q at 12.5 gm/lit and Fruit boost at 0.5 ml/lit of watermelon plots meagerly attracted a number of bee foragers than the control plots.

2.2. Effect of pollination on seed and yield contributing characters of bitter gourd

McGregor (1950) observed that to get maximum quantity and better quality of melons, sufficient population of honey bees should be present throughout the flowering period.

McGregor and Todd (1952) found that no melon fruit set until the bees were introduced into caged melon plot, but when honey bees were introduced, there was a rapid fruit set resulting in the production of 184 good quality marketable melons. But, the open melon plots produced only 145 melons as against four in plots caged without honey bees.

Mann (1953) observed that 66.60 per cent of fruit set was obtained from bee pollination, which was higher than 38.70 per cent of cantaloupe fruit set was obtained by hand pollination.

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

Shemetkov (1957) reported that a number of workers claim to ensure cucumber pollination on yield parameters with eight visits / flower.

Adlerz (1960) found that the watermelon fruit set was significantly better after eight or more bee visits per flower.

Verdieva and Ismailova (1960) reported 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 methods.

Adlerz (1961) observed that six or more bee visits per flower were significantly better than four or fewer bee visits per flower in watermelon.

Wolfenbarger (1962) demonstrated the value of bees as pollinators in three ways; firstly, in all the three years he caged squash plants to without insects and found that the average yield was only 19 per cent; secondly, he observed that the yield of fruits decreased with distance from a group of 20 honey bee colonies put at one end of the field and thirdly, he reported that a positive correlation between the number of honey bee colonies per acre and the number of fruits obtained. He had got 148 baskets of fruit in a field where no colonies were provided, 155 baskets in less than one colony / acre (1 or 2 colony), 161 baskets in one colony / acre, 168 baskets in two colonies / acre and 173 baskets of fruit in field provided with three honey bee colonies / acre.

Mcgregor *et al.* (1965) showed that a number of workers claim to ensure cucumber pollination on yield parameters with eight visits per flower. 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 and also found that the per centage of marketable melon increased with the number of bee visits. 10 bee visits / flower were enough.

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

Battaglini (1969) showed in *C. pepo* that 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 %, when flowers were caged.

Conner (1969) reported that a single bee visit to pistillate flower often resulted in better-shaped cucumber fruits and also found that bee visits was positively co-related with increase in number of seeds per fruits, fruit weight in cucumber.

Conner and Martin (1969) reported 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.

Stephen (1970) found that at least 10 bee visits were necessary to ensure pollination under all the conditions, whereas eight to twelve visits per blossom were needed to yield uniform sized cucumber.

Steinhauer (1971) reported that the cucumber yield was increased by 39 per cent with one honey bee colony / acre as compared to fields without bees.

Kauffeld and Williams (1972) reported that honey bee pollination has increased the average weight and quality of cucumbers both in open and plots caged with honey bees.

Kauffeld *et al.* (1975) found that the yields of muskmelon fruits were higher in plants pollinated by bees and plants in which bees were excluded set practically no fruits.

Brewer (1974a) reported that honey bees were the adequate pollinators of watermelon in USA. Experiments in which pumpkin (*C. moschata*) flowers were bagged to exclude bee visits and exposed to number of bee visits shown that the fruits set were 6.5 per cent after one visit and 64.5 per cent after 12 visits per flower.

Brewer (1974b) observed that the high correlation between melon weight, number of mature seeds (r=0.90) and weight of mature seeds (r=0.85), but contrary to very low correlation between melon weight and immature seeds. He also found that more number of melons was harvested from the plots visited by bees than from those where bees were excluded.

Jaycox *et al.* (1975) reported that the pumpkin weight and number of seeds with increased with number of visits.

Collison (1976) claimed that 15 to 20 bee visits were needed to get uniform cucumbers and more bee visits were increased the average number of seeds, which resulted in better and maximum fruit weight.

Sunder (1978) studied that among the different modes of pollination tried and obtained 326 watermelon fruits in bee pollination which was at par 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 with 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 per centage of bold viable seeds shows 46% which was more compared to the other two modes of pollination (about 27%). The dry weight of bold viable seeds was found around 4 kg in natural and hand pollinated flowers compared to bee-pollinated flowers (7 kg).

Spangler and Moffett (1979) recorded 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) reported that 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* which are solitary bees were enclosed respectively in caged plots.

Kauffeld and Nelson (1982) found 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) observed that in bottle gourd 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.

Williams (1987) in Australia, reported that 20, 26 and 27 melons from the plots caged to exclude bees, caged with honey bees and not caged, with an average 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 rock melon weight by 40 per cent and increased number of rock melons by 25 per cent.

Mohan Rao and Suryanarayana (1988) obtained results as 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) found 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) recorded 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 which shows 33 %. Bee and open pollination also yielded with high weight and uniform fruits.

Elmstrom and Maynard (1991) studied that application of two application of Bee scent (a liquid formulation containing 9.00 per cent pheromone 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 up to 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 were not affected by the treatment. The number of seeds/fruit was higher with treatment on three frames.

Gaye *et al.* (1991) found 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) studied by application 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 lit/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).

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

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*). Fruit set and number of filled seeds was significantly higher in plots with 0.5 colonies per 2000 plants and over population caused competition for flower, thus reducing pollination efficiency. Honey bees (*A. mellifera*) constituted 82.6 % of visitor to cucumber flowers.

Nogueira coutao and Calmona (1993) studied that plots caged 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.

Froissart *et al.* (1995) recorded best results from with bees (*A. mellifera*) in sealed polyethylene tunnels which yielded 0.97 kg export grade fruits per plants compared to sealed polyethylene tunnels open at one end which gave 0.56 kg per plant.

Bernard *et al.* (1996) studied on honey bees (*A. mellifera*) under covered. *A. mellifera* yielded good fruit size and good number of seeds and commercial grade fruit than control plots.

Anonymous (1999) Total number of watermelon fruits per plot was maximum with 25.53 fruits in plots treated with Bee-Q @ 15.00 gm/lit, 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 ton/ha was recorded in plots where Bee-Q was sprayed @ 12.5 gm/lit, which was on par with 15.00 gm/lit, the lowest yield was obtained in control and water spray with showing observations 8.14 and 9.00 ton/ha, respectively.

Eswarappa (2001) noticed that maximum fruit set 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 i.e. 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 minimum 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.

Sattigi *et al.*, (2001) studied that application of Bee-Q at concentration 12.50 and 15.00 gm/lit resulted in higher yield (19.56 and 19.45 ton/ha respectively), maximum good fruits, minimum malformed fruits and higher size and weight in watermelon.

William Rajasekhar (2001) recorded the effect of the bee pollination on water melon. Significantly higher fruits per 30 m^2 were found 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) observed 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 two times, one spray of Bee-Q, Bee-here and sugar solution. In contrast, lowest numbers of malformed fruits were recorded in the treatments that received two sprays of attractants with 12.75 fruits/plot and were 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) showed 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 with 15.61 fruits/plant vs. 7.42 and 3.34 without bees, respectively and fruit weight (126.11 gm/fruit).

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

in the yield of 34.28 and 101.84 % over open pollination without spray and caged plot without bees, respectively.

Nidagundi (2004) found that significantly highest length of fruits in bitter gourd 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 129.20 as against 72.09 and 62.44 in open pollinated and caged plot without bees, respectively as well as yield of 118.87 quintal as against 68.63 and 45.23 quintal in open pollinated and caged plots without bees, respectively.

G. Subhakar *et al.* (2011) recorded that 14 insect species including 6 hymenopterans, 5 lepidopterans and 3 dipterans were visiting the bitter gourd flowers. Among them, *T. iridipennis, Halictus gutturosus* and *A. florea* were the most frequent and abundant visitors. . Foraging activity of *T. iridipennis, A. florea* and *H. gutturosus* commenced at 06:00, 06:30 and 07:30 h, respectively with peak at 09:00-10:00 h and ceased by 14:00, 12:30 and 13:00 h, respectively.

Jayaramappa *et al.* (2011) observed that Bee-Q @ 10, 12,5 and 15 gms/lit, Fruit boost @ 0.50, 0.75 and 1 ml/lit, Cinnamon leaf extract @ 5%, Tuberose floral scented water, 10% sugar solution on ridge gourd and crop deprived is control, which is open pollinated. Spraying of Fruit boost @ 0.5 ml/lit and Bee-Q @ 12.5 gm/lit enhanced yield parameters like number of fruits per plant to 19.00 and 17.00 fruits, when compared to 10.66 fruits per plant in open pollinated plot. Number of fruits was 21.83 and 20.83 fruits per plot, when compared to15.68 fruits per plot in open pollinated plots.

Pavana Kumar Balina *et al.* (2012) observed than nine bee species of three families (Apidae, Halictidae and Megachilidae) as visitors to bitter gourd flowers. Amongst these, *Halictus sp., Megachile sp*. and *Apis dorsata* Fabricius were found to be the most frequent visitors. The abundance of *Halictus sp*. was highest, followed by *Megachile sp*. and *A. dorsata*. *A. dorsata* was the most efficient pollinator of bitter gourd, followed by *Halictus sp.* and *Megachile sp.*

Mary Lucy Oronje *et al.* (2012) reported that pollinator species in *M. charantia* included honey bees (*Apis mellifera), Plebeina hildebrandti, Lasioglossum sp.* and carpenter bees (*Xylocopa spp*). Fruit set under natural pollination was very low and this revealed the degree of pollen limitation in *M. charantia*. Low fruit set was consistent with high discrimination against pistillate flowers amongst potential pollinators. Smaller bees belonging to families Apidae (*Plebeina hildebrandti*) and Halictidae (*Lasioglossum sp*.) were the important pollinators.

Shafqat Saeed *al.* (2012) found that the pollinator community was composed of 15 insect species in 3 orders and 10 families. Bees were the most dominant (435 individuals) floral visitors.

A. florea, Parnara guttata and *A. dorsata* were the most abundant pollinators. *A. florea* and *A. dorsata* also exhibited the highest visitation rates and frequencies. 5 major pollinators were tested for their single-visit efficacy, showing that *A. dorsata* was the most effective pollinator, along with *A. florea* and *Eristalinus laetus*. Conserving and enhancing these pollinators may enhance *M. charantia* production in Pakistan.

Sushil *et al.* (2013) observed that bees in the open conditions were found to spend less time in a flower as compared to the net house conditions. Honey bees played an important role in increasing the seed production of all the crops under study. The net profit was also more in case of broccoli, which was calculated to be 1324.60$ / ha in honeybee pollinated broccoli crop when compared to the natural pollinated crop.

Imran Bodlah and Muhammad Waqar (2013) reported that the forging activity of insect pollinators visiting the summer vegetables i.e. Ridge gourd (*Luffa acutangula*), Bitter gourd (*Momordica charantia* L.) and Eggplant or Brinjal (*Solanum melongena*). Two orders Hymenoptera and Diptera were identified as the major pollinators of these vegetables. The order Hymenoptera includes six species (*Apis Sp., Bombus sp., Xylocopa sp., Halictus sp.* and two unidentified species one from Halictidae family and one from Megachilidae family).

Rajesh Kumar and Vinod Kumar (2014) found that the influence of pollination by *Apis mellifera* on fruit set, yield and quality of litchi fruits. The results revealed that insects visiting litchi flowers were mainly bee species (*Apis mellifera, A. dorsata, A. cerana indica* and *A. florea*), flies, wasps and beetles. *A. mellifera* was recorded as the dominant forager on litchi flowers (48.13%) followed by *A. cerana indica* (37.16%). The highest foraging activity of *A. mellifera* was at 08:00 am followed by 10:00 am in both open and controlled pollination conditions observed maximum foraging activity.

Gogoi *et al.* (2014) reported that hymenoptera included nine species (*Xylocopa fenestrate, X. leucothorax, Apis cerana, Solenopsis geminate, Polystis haebreus, Vespa orientalis, Sphecodes fumipennis, Pompilus bracatus* and *Thersilochus sp.* The foraging behaviour of *X. fenestrata* such as frequency of flower visit, pollen load per trip, time taken per trip and time spent per flower were observed showing significant differences.

Chhayani and Patel (2014) found that foraging activity of *A. florea* and *A. dorsata* on bajara started either at 8:00 or 10:00 hrs. Thereafter, it declined up to 14:00 hr. The activity again started increasing from 16:00 hr and reached to maximum at 18:00 hr. on sorghum, The foraging activity of *A. florea* started with maximum at 8:00 hr (1.12 bees/5 min./m^2) and thereafter, it was found almost equal up to 18:00 hr.(0.75 to 0.62 bee/ 5 min./m^2).

Subhakar and Sreedevi (2015) showed three major pollinators and revealed that *A. florea* spent less time on flowers. The maximum time spent by *A. florea* was 14.26 s with average foraging time of 9.28 s per flower. This was recorded during the peak foraging hour of all three bee species. These findings are in close proximity with the earlier reports.

Shah *et al.* (2015) investigated that the population density of insect pollinators on four different varieties (Peshawar Local, Beta Alpha, Market More and Moon Star (hybrid)) of cucumber and also to evaluate their impact on the yield of cucumber. The results regarding average population of pollinators showed the highest population of honey bees (1.21/plot) among all pollinators and varieties while population of carpenter bees was recorded to be the lowest (0.03 per plot). Population density of pollinators was observed to be highest during morning and evening times. Uncovered plots yielded significantly higher than covered without insect plots in all the comparative treatments.

Singh *et al*. (2015a) recorded that the abundance and foraging activity of different bee visitors to pigeon pea (*Cajanus cajan* L.) Millsp) cultivar ICPL–151 and Bahar. The four species of bees were recorded visiting the flowes viz. *Megachile sp., Apis florae, A. cerana indica* and *A. mellifera* and five species of bees namely *A. mellifera, A. dorsata, A. florae, A. cerena indica* and *Megachile spp*. of both cultivars respectively.

Singh *et al*. (2015b) found that the mean number of *Apis mellifera* collecting pollen and both nectar and pollen was found to be 14.71 + 2.47 and 3.71 + 0.65 per hour, respectively. The pollen collecting activity reached its peak at 13:00 hrs after that it began to declined.

Rojeet Thangjam *et al.* (2016) recorded that *A. dorsata, A. cerana indica, A. florae, Xylocopa fenestrata, Andrena sp., Nomia sp., Eristalinus arvorum, E. taeniops, E. punctulatus, Erisyrphus balteatus* and *Pieris napi* as pollinators in rapeseed. Out of these, 6 species of pollinators viz., *X. fenestrata, Andrena sp., Nomia sp., E. taeniops, E. punctulatus,* and *P. napi* were abundant.

3. MATERIAL AND METHODS

The investigation entitled “studies on role of honey bees as a pollinator on seed production of bitter gourd (*Momordica charantia* L.)” was carried out during the *Rabi* 2016. The details of materials used and methods adopted during the present investigation are described in this chapter.

3.1. Place of Research work:

The research work was conducted at research farm of All India Coordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri.

3.2. Geographical area

Geographically, central campus of M.P.K.V., Rahuri is situated at 19^0 47’ and 19^0 55’ North latitude and 74^0 19’ and 74^0 42’ East Longitude with elevation of 525 meter above the mean sea level. The track is lying on the eastern side of western ghat and comes under rain shadow area.

3.3. Climate

Climatologically, this area falls in the scarcity zone with an annual rainfall ranging from 317 to 619 mm. The average annual rainfall is 520 mm. The rainfall is erratic and ill distributed in 15 to 45 rainy days. Of total annual rainfall, about 80 per cent is received from South-West monsoon while rest is received from North-East monsoon and practically negligible rainfall is received during summer.

The annual mean temperature is 32 ^{0}C with range between 24.4 ^{0}C and 40.5 ^{0}C and annual mean minimum temperature is 17.6 ^{0}C. The mean relative humidity at 08.00 and 14.00 hrs is 72.82 and 37.52 per cent, respectively. Agro climatically, the location is in the drought prone area of Maharashtra.

3.4. Soil

The topography of the field was fairly uniform and leveled. The soil of experimental area was medium black, moderately fertile with adequate drainage.

3.5 Material

3.5.1 Seeds

The seeds of bitter gourd cv. ‘Phule green gold’ were used for sowing. The seeds were made available through All India Co-ordinated Research Project on Vegetable Crops, Department of Horticulture, MPKV, Rahuri. Dist. Ahmednagar.

3.5.2 Bee attractants and appliance

The various indigenous bee attractants used during investigation were obtained from local market.

Appliance used for spraying of bee attractants was knapsack sprayer made available by All India Co-ordinated Research Project on Vegetable Crops, Department of Horticulture, Department of Agricultural Entomology, and Electronic weighing balance, seed counter were made available by Seed Technology Research Unit, MPKV, Rahuri, Dist. Ahmednagar.

3.6. Methodology:

A. Experimental details

1.	Crop	:	Bitter gourd
2.	Variety	:	Phule green gold
3.	Design	:	Randomized Block Design (RBD)
4.	Treatments	:	9
5.	Replications	:	3
6.	Plot size	:	15 x 1.5 m.
7.	Season	:	Rabi, 2016
8.	Date of Sowing	:	16 August, 2016
9.	Spacing	:	150 x 60 cm
10.	Date of Spraying	:	First : 7 October, 2016 Second : 15 October, 2016
11.	Harvesting of Fruits for Seed Production	:	20 October, 2016 to 30 January, 2017

B. Treatment details:

SN	Treatment No.		Treatment
1.	T_1	:	Open pollination
2.	T_2	:	Pollination without insect
3.	T_3	:	Coconut water 10%

4.	T_4	:	Sugar solution 10%
5.	T_5	:	Sugarcane juice 10%
6.	T_6	:	Jaggery solution 10%
7.	T_7	:	Molasses 10%
8.	T_8	:	Honey solution 10%
9.	T_9	:	Pomegranate juice 5%

The crop which did not received any spray of attractant served as open pollination (T1) and the crops which was caged with nylon mesh before initiation of flowering to seed set served as pollination without insect (T2).

3.7. Methodology adopted for observations

Methodologies adopted to study the various observations were as follows.

3.7.1. Foraging activity of honey bees on cucumber

Observations were recorded by randomly selecting one square meter area from each plot and number of different species of honey bees visiting these flowers per minute were recorded from 08.00 hrs to 18.00 hrs, at an interval of two hours, such observations were recorded at weekly interval during flowering period. The data was averaged time wise and species wise to draw the conclusion on foraging behavior of honey bees.

3.7.2. To study the effect of bee attractants on activities of honey bees in bitter gourd

The attractants were sprayed two times, first at 10 per cent and second at 50 per cent flowering stages. The crop was protected from various pests and diseases but no insecticides were used during the flowering period. Recommended agronomical package of practices were followed for raising good seed production plot.

- **Number of bees visiting per one meter square area**

  In each plot one meter square area was randomly selected and number of different species of honey bees visited the flowers per minute was recorded during its peak period. Such observations were recorded a day before the first and second spray and later on 1^{st}, 3^{rd}, 5^{th} and 7^{th} days after 1^{st} and 2^{nd} spray. Means of all observations were pooled for *A. dorsata*, *A. cerana indica* and *A. mellifera* separately. The data from individual observation were subjected to statistical analysis.

- **Number of flowers visited by single bee per minute**

Number of flowers visited by single bee per minute was recorded in all the treatment except in pollination without insect. Efficient foraging activity by different species of bees was observed by recording the visits of *A. dorsata, A.cerana indica* and *A. mellifera* separately.

3.7.3 To study the effect of honeybee on seed yield and yield contributing characters of bitter gourd

The following yield contributing parameters were recorded to know the role of bee pollination in enhancing the productivity of bitter gourd.

- **Number of fruits per plant**

In each plot ten plants were selected randomly and number of fruits in these plants were counted. Average of fruits per plant was worked out from it.

- **Number of seeds per fruit**

This observation was made by selecting fifteen fruits at random from each replication of treatment during harvesting. The seed in each fruits was counted and mean seeds per fruits were calculated.

- **Per centage of undeveloped seeds or wrinkled seeds**

Similarly from selected fifteen fruits, number of healthy seeds and undeveloped seeds were separated and per centage of undeveloped seed was calculated by using formula:

$$\text{Per cent wrinkled seeds/fruit} = \frac{\text{No. of undeveloped seeds/fruit}}{\text{Total number of seeds/fruit}} \times 100$$

- **Test weight (weight of 100 seeds)**

This observation was recorded by weighing 100 dried seeds sample randomly from each replication of treatment by using electronic weighing balance and determined in grams.

- **Yield of five plant in kg**

Harvesting of randomly selected five plants from each replication of treatment was done and yield was determined in kilograms.

- **Seed yield in Qtl/ha**

Each plot was harvested, weighted separately and the yield per plot was later converted into yield per hectare.

3.8. Statistical analysis

The experimental data were subjected to statistical analysis as per the method of statistical analysis of randomized block design as suggested by Panse and Sukhatme (1978). The significance of treatment was assessed on the basis of determining critical difference (CD) at 5% level of significance. Data on number of bees were converted into square root transformed value ($\sqrt{x + 0.5}$) and subjected to statistical analysis.

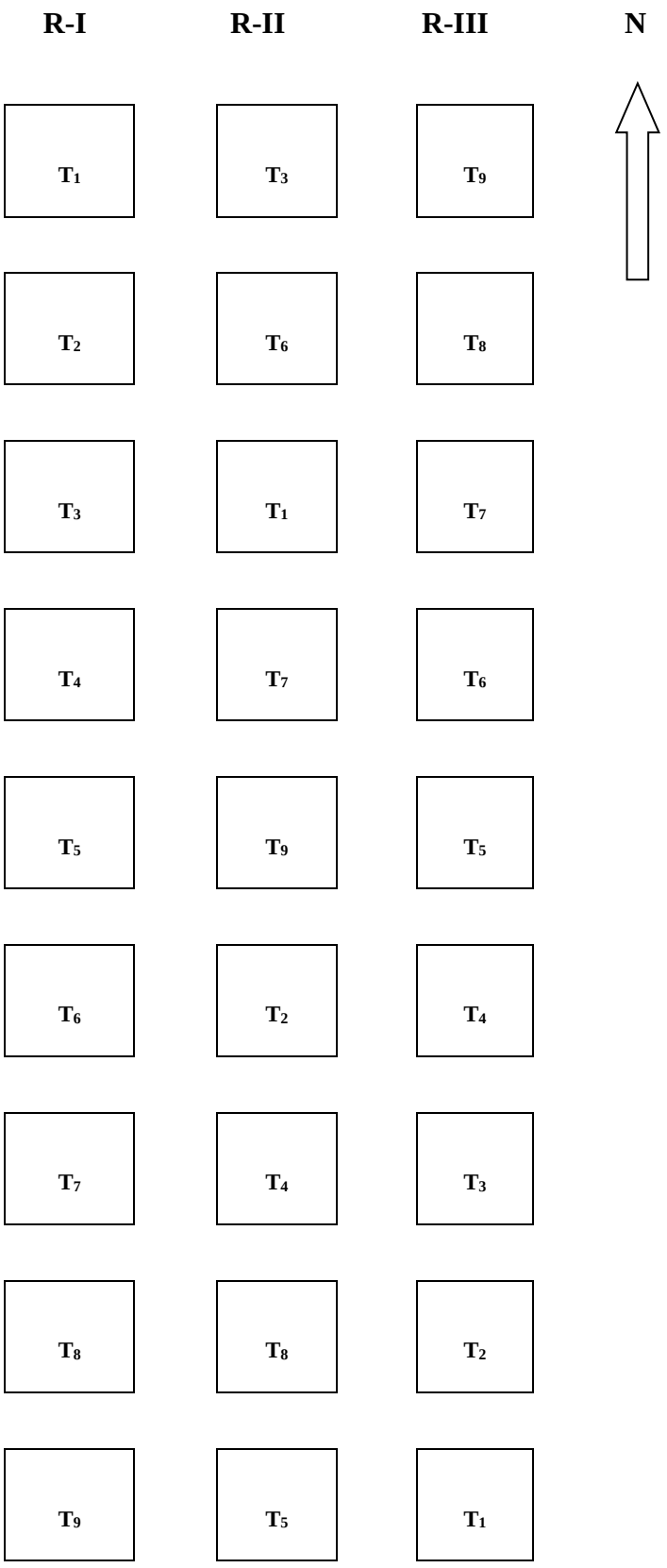

Fig 1. Lay out of experimental plot

4. RESULTS AND DISCUSSION

The results of the studies carried out on foraging activity of honey bees, effect of bee attractants on activity of bees and effect of honey bee pollination on seed yield and yield contributing characters of bitter gourd are presented in this chapter.

4.1 Foraging activity of honey bees on bitter gourd

The results on foraging activity of different honey bee species and pollinators are presented in following tables.

4.1.1 Foraging activity of pollinators on bitter gourd

The data on foraging activity of different pollinators on bitter gourd crop is presented in Table 1.

During study of foraging activity of different pollinators eleven species of pollinators are observed out of which nine hymenopterans and two are dipteran insect species on flowers. Among these, major pollinating species of Honey bees were *Apis cerana indica* (31.57 %), *Apis dorsata* (26.31 %), *Apis mellifera* (22.36 %) and in other pollinators *Helictus spp*. (11.84 %), *Megachile spp*. (5.26 %) *Coelioxys spp.* (2.63 %) also observed as relatively minor pollinators.

Table 1.Pollinators fauna of bitter gourd

Sr. No.	POLLINATORS	SYSTEMIC POSITION		RELATIVE ABUNDANCE %
		ORDER	FAMILY	
1	*Apis dorsata*	Hymenoptera	Apidae	26.31
2	*Apis mellifera*	Hymenoptera	Apidae	22.36
3	*Apis cerana indica*	Hymenoptera	Apidae	31.57
4	*Nomia spp.*	Hymenoptera	Helictidae	
5	*Helictus spp.*	Hymenoptera	Helictidae	11.84
6.	*Trigona irridipennis*	Hymenoptera	Miliponidae	
7	*Megachile spp.*	Hymenoptera	Megachilidae	5.26
8	*Coelioxys spp.*	Hymenoptera	Megachilidae	2.63
9	*Xylocopus spp.*	Hymenoptera	Xylocopidae	
10	*Erastalinus arvorum*	Diptera	Syrphidae	
11	*Bombilinus spp.*	Diptera	Bombilidae	

4.1.2 Foraging activity of *A. dorsata* on bitter gourd

The data on foraging activity of *A. dorsata* on bitter gourd crop is presented in Table 2 and depicted in figure 2.

Table 2. Foraging activity of *A. dorsata* on bitter gourd

Sr. No.	Hours	Number of bees/m^2/min				Total	Average
		1st week	2nd week	3rd week	4th week		
1.	8:00	0.6	0.4	0.6	0.4	2.0	0.50
2.	10:00	2.8	1.0	1.2	1.4	6.4	1.60
3.	12:00	4.4	1.4	1.4	2.0	9.2	2.30
4.	14:00	1.6	0.6	0.6	0.8	3.6	0.90
5.	16:00	0.8	0.8	0.8	1.0	3.4	0.85
6.	18:00	0	0	0	0	0.0	0.00
7.	**Total**	10.2	4.2	4.6	5.6	24.6	
8.	**Average**	1.70	0.70	0.78	0.93		

Foraging behavior of *Apis dorsata* on bitter gourd was recorded from 08.00 hrs to 18.00 hrs, at two hourly intervals, such observations were made at weekly interval.

On an average, number of *Apis dorsata* on bitter gourd plot was 1.70 bees/m^2/min visited during first week after 10 per cent flowering. Bee activities decreased in second week but again increase gradually and attained 0.78 bees/m^2/min on 3rd week after 10 per cent flowering. However, on 4th week after 10 per cent flowering on an average of 0.93 bees/m^2/min was recorded.

Also *Apis dorsata* has minimum foraging activities at morning hours but increases gradually and attain maximum foraging activity at 10:00 to 12:00 hours on an average of 2.30 bees/m^2/min. Again it decreases at evening hours and attain 0.85 bees/m^2/min at 16:00 hours and become zero at 18:00 hours.

The present findings are in agreement with report of Sattagi *et al.* (2001), Nidagundi (2004), Subhakar *et al.* (2011) who reported that rock bee initiated foraging at 08.00 hrs and peak was attained at 12.00 hrs.

4.1.3 Foraging activity of *Apis cerana* indica on bitter gourd

The data on foraging activity of *Apis cerana indica* on bitter gourd crop is presented in Table 3 and depicted in figure no.3.

The comparative foraging activity of *Apis cerana indica* during different weeks after 10 per cent flowering indicated that the total number of bees that visited the bitter gourd plot during the flowering period were 28.60 visits of bees in 24 minutes. During the first week after 10 per cent flowering, *Apis cerana indica* visited the bitter gourd plot with an average of 1.40 bees/m^2/min later attained during 2nd week after 10 per cent flowering with an average of 1.36 bees/m^2/min. It again attain 1.40 bees/m^2/min in 3rd week. Thereafter gradually decreased on 4th week after 10 per cent flowering with an average of 0.60 bees/m^2/min.

Table 3. Foraging activity of *A. cerana* on bitter gourd

Sr. No.	Hours	Number of bees/m^2/min				Total	Average
		1st week	2nd week	3rd week	4th week		
1.	8:00	1.0	1.2	1.2	0.4	3.8	0.95
2.	10:00	2.8	2.6	2.6	0.6	8.6	2.15
3.	12:00	2.2	1.8	2	1.4	7.4	1.85
4.	14:00	1.6	1.2	1.2	0.8	4.8	1.20
5.	16:00	0.8	1.4	1.4	0.4	4.0	1.00
6.	18:00	0	0	0	0	0.0	0.00
7.	**Total**	8.4	8.2	8.4	3.6	28.6	
8.	**Average**	1.40	1.36	1.40	0.60		

Similarly, when the bee foraging activity was compared between different hours of the day, it revealed that the *A. cerana indica* started visiting the bitter gourd plot early at 08.00 hrs with an average of 0.95 bees/m^2/min. It gradually increased and peak activity was observed at 10.00 hrs

with an average of 2.15 bees/m^2/min. Thereafter it decreases gradually and at 16:00 hours with an average of 1.00 bees/m^2/min and at 18.00 hrs with an average of 0.00 bees/m^2/min.

These findings are in agreement with the reports of Rajesh Kumar and Vinod Kumar (2014) who reported the activity of *A. cerana* was maximum between 08.00 hrs to 10.00 hrs.

4.1.4 Foraging activity of *Apis mellifera* on bitter gourd

The data on foraging activity of *A. mellifera* on bitter gourd crop is presented in Table 4 and depicted in figure no.4

The comparative study indicate that the foraging activity during first week, the average foraging activity of *A. mellifera* was 0.73 bees/m^2/min and peak was 1.03 bees/m^2/min attained during second and third week, later, it reached average of 0.60 bees/m^2/min during 4^{th} week after 10 per cent flowering.

It was observed that foraging activity of *Apis mellifera* found to be more as compared to other pollinators regarding with time period which was the highest on 12.00 hrs (1.70 bees/m^2/min) followed by 10.00 hrs (1.15 bees/m^2/min). The lowest number of bees was recorded at 18.00 hrs (0.00 bees/m^2/min).

Table 4. Foraging activity of *Apis mellifera* on bitter gourd

Sr. No.	Hours	Number of bees/m^2/min				Total	Average
		1st week	2nd week	3rd week	4th week		
1.	8:00	0.4	1.0	1.0	0.4	2.8	0.70
2.	10:00	1.2	1.4	1.4	0.6	4.6	1.15
3.	12:00	1.4	2.0	2.0	1.4	6.8	1.70
4.	14:00	0.8	0.8	0.8	0.8	3.2	0.80
5.	16:00	0.6	1.0	1.0	0.4	3.0	0.75
6.	18:00	0	0	0	0	0.0	0.00
7.	**Total**	4.4	6.2	6.2	3.6	20.4	
8.	**Average**	0.73	1.03	1.03	0.60		

4.1.5 Foraging activity of other pollinators on bitter gourd

The data on foraging activity of other pollinators on Bitter gourd crop is presented in Table 5 and in figure no 5.

Foraging activity of other pollinators on bitter gourd was observed from 08.00 hrs to 18.00 hrs. During 1st week, the average foraging activity was 2.96 pollinators/m^2/min. During second week, it was 3.10 pollinators/m^2/min and 3.03 pollinators/m^2/min during 3rd week, later it reached peak with average of 3.30 pollinators /m^2/min during 4th week after 10 per cent flowering.

Similarly, comparing with different hours of the day, peak activity was observed at 12.00 hours with an average of 4.15 pollinators/m^2/min followed by 14.00 hours which recorded 3.85 pollinators/m^2/min. After 12.00 hours, it is gradually decreased and lowest number of pollinators was recorded at 18.00 with an average of 1.30 pollinators /m^2/min.

Table .5 Foraging activity of other pollinators on bitter gourd

Sr. No.	Time (hours)	Number of other pollinators /m^2/minute					
		1st week	2nd week	3rd week	4th week	Total	Average
1.	08:00	2.80	3.00	2.20	2.80	10.80	2.70
2.	10:00	3.20	3.40	3.40	3.60	13.60	3.40
3.	12:00	4.20	3.80	3.40	5.20	16.60	4.15
4.	14:00	3.80	3.80	4.20	3.60	15.40	3.85
5.	16:00	2.40	3.60	3.60	3.20	12.80	3.20
6.	18:00	1.40	1.00	1.40	1.40	5.20	1.30
7.	**Total**	17.80	18.60	18.20	19.80	74.40	
8.	**Average**	2.96	3.10	3.03	3.30		

4.1.6 Comparative foraging activity of different pollinators on bitter gourd

The data on foraging activity of other pollinators on bitter gourd crop is presented in Table 6 and depicted in figure no.5.

Table.6: Comparative Foraging activity of different pollinators on bitter gourd

Sr. No.	Time (Hours)	*Apis dorsata*	*Apis cerana indica*	*Apis mellifera*	Others	Total	Average
1.	08.00	0.50	0.95	0.70	2.70	4.85	1.21
2.	10.00	1.60	2.15	1.15	3.40	8.30	2.07
3.	12.00	2.30	1.85	1.70	4.15	10.00	2.50
4.	14.00	0.90	1.20	0.80	3.85	6.75	1.68
5.	16.00	0.85	1.00	0.75	3.20	5.80	1.45
6.	18.00	0.00	0.00	0.00	1.30	1.30	0.32
7.	**Total**	6.15	7.15	5.10	18.60	36.84	
8.	**Average**	1.02	1.19	0.85	3.10		

The data recorded on foraging activity of different pollinators on bitter gourd revealed that the *A. cerena* were large in number (1.19 bees/m^2/min) as compared to *A. dorsata* (1.02 bees/m^2/min), *A. mellifera* (0.85 bees/m^2/min) and other pollinators (3.10 pollinators/m^2/min) respectively. As compared with different time duration, maximum number of bees visited during 12.00 hrs 2.50 bees/m^2/min) followed by 10.00 hrs (2.07 bees/m^2/min) and The lowest number of bees recorded in 18.00 hrs (0.32 bees/m^2/min). This results were plotted in figure no. 6.

4.2 Number of flowers visited by single bee per minute

The results pertaining to the number of flowers visited by single bee per minute is presented in Table 7 indicated that the number of flowers visited by single bee per minute, in that *Apis cerena indica* was an efficient forager and visited more number of flowers (1.19 bees/m^2/min) per unit time followed by *A. dorsata* (1.02 bees/m^2/min) and *A. mellefera* (0.85 bees/m^2/min) in bitter gourd filed.

Table 7.Number of flowers visited by single bee/minute in bitter gourd

Sr. No.	Pollinators species	No. of flowers visited by single bee/minute/m^2
1	*Apis dorsata*	1.02
2	*Apis cerana indica*	1.19
3	*Apis mellifera*	0.85

4.3 Influence of bee attractant on bee activity on bitter gourd

4.3.1 Influence of bee attractant on activity of *Apis dorsata* on bitter gourd

Data pertaining to the effect of bee attractants to attracting *A. dorsata* on Bitter gourd after 10 per cent and 50 per cent flowering are presented in Table 8.

First spray

A day before spraying of attractants, the bee activity was ranged from 1.21 to 1.66 bees/m²/min.

The effectiveness of the treatment on 1 day after spraying with 10 per cent molasses, 10 per cent jaggary solution and 10 per cent honey solution were found to be the best treatment in attracting higher number of bees (3.77, 3.77 and 3.66 bees/m²/min respectively). The next best treatment was crop sprayed with sugarcane juice 10 per cent (3.21 bees/m²/ min) followed by sugar solution 10 per cent (2.99 bees/m²/min) were found at par.

On 3rd day after the first spray, honey solution 10 per cent (2.10 bees/m²/ min) was significantly superior in attracting more number of bees over the rest of the treatments. Next bee activity was recorded in the plot sprayed with molasses 10 per cent, sugar solution 10 per cent and jaggary solution 10 per cent bees with 1.66, 1.22 and 1.21 bees/m²/min respectively. The lowest bees were observed in treatments with open pollination (0.77 bees/m²/min).

On 5th day after first spray, the same trend was observed. The treatment honey solution 10 per cent recoded significantly higher number of bees (1.55 bees/m²/min) was significantly superior over all treatments followed by molasses 10 per cent with 1.33 bees/m²/min. The next better treatments were sugarcane juice 10 per cent (1.10 bees/m²/ min), coconut water 10 per cent (0.99 bees/m²/ min) and sugar solution 10 per cent (0.88 bees/m²/ min). However, the least number of bees were observed in crop with open pollination (0.77 bees/m²/ min).

On 7th day after spray no specific results of bee attractants were observed and was showed the result relatively similar to observations of one day before spraying of bee attractants.

On an average honey solution 10 per cent showed relatively highest bee activities with 1.93 bees/minute/m^2 followed by molasses 10 per cent with 1.88 bees/minute/m^2 and jaggary solution 10 per cent with 1.65 bees/minute/m^2. Open pollination had showed least bees activities.

Second spray

Before second spray, the visitation of *Apis dorsata* was recorded on one day before spray was in the range of 0.44 to 0.88 bees/m^2/min.

One day after second spraying, the treatment with molasses 10 per cent and honey solution 10 per cent were found significantly superior in attracting more number of bees (2.22 and 2.21 bees/m^2/min) and was at par with sugarcane juice 10 per cent (1.66 bees/m^2/min). Jaggery solution 10 per cent and sugar solution 10 per cent (1.55 bees/m^2/min) were next better treatments. Open pollination (without spray) recorded the lowest number of bees (0.99 bees/m^2/min).

Among different treatments, spraying of honey solution 10 per cent was found to be superior compared to other treatments (2.10 bees/m²/ min) on the 3rd day after spray and was at par with molasses 10 per cent (1.77 bees/m²/min) followed by jaggery solution 10 per cent (1.66 bees/m²/min) and sugarcane juice 10 per cent (1.44 bees/m²/ min). However, the treatment with open pollination, which recorded as 0.99 bees/m²/min found to be lowest bee attracting treatment.

On 5th day after second spray, honey solution 10 per cent attracted maximum number of bees (1.33 bees/m²/min) and found at par with molasses 10 per cent (1.21 bees/m²/min). Further, crop sprayed with jaggery solution 10 per cent (0.99 bees/m²/min) cent also next best treatment but the open pollination plot was ineffective in attracting more bees (0.66 bees/m²/min).

Similarly On 7th day after second spray treatment honey solution 10 per cent (0.99 bees/m^2/min) found significantly superior compared to other treatments. The next better treatments were molasses 10 per cent, jaggary solution 10 per cent, sugar solution (0.77 bees/m^2/min) and sugarcane juice 10 per cent, pomegranate juice 10 per cent and coconut water 10 per cent (0.66 bees/m^2/min). Open pollination without spray recorded lowest number of bees (0.66 bees/m^2/min).

The results obtained from the present study are in line with report of Virakthamath and Anagoudar (2002), Nidagundi (2004), Jayaramappa *et al.* (2011).

Table 8. Influence of bee attractants on activity of *A. dorsata* on bitter gourd

Sr. No.	Treatment	Number of bees per square meter per minute													
		1st spray at 10 per cent flowering							2nd spray at 50 per cent flowering						
		1 DBS	1 DAS	3 DAS	5 DAS	7 DAS	Total	Average	1 DBS	1 DAS	3 DAS	5 DAS	7 DAS	Total	Average
1.	Open Pollination	1.33 (1.35)	1.66 (1.46)	0.77 (1.12)	0.77 (1.12)	0.44 (0.96)	3.64	0.91	0.44 (0.96)	0.99 (1.22)	0.99 (1.22)	0.66 (1.07)	0.66 (1.07)	3.30	0.82
2.	Coconut Water 10%	1.44 (1.39)	2.77 (1.80)	0.88 (1.17)	0.99 (1.22)	0.55 (1.02)	5.19	1.29	0.55 (1.02)	1.21 (1.30)	1.1 (1.26)	0.66 (1.07)	0.66 (1.07)	3.63	0.90
3.	Sugar Solution 10%	1.44 (1.39)	2.99 (1.86)	1.22 (1.30)	0.88 (1.17)	0.88 (1.17)	5.97	1.49	0.88 (1.17)	1.55 (1.43)	1.33 (1.35)	0.88 (1.17)	0.77 (1.12)	4.53	1.13
4.	Sugarcane Juice 10%	1.55 (1.43)	3.21 (1.92)	1.11 (1.26)	1.1 (1.26)	0.55 (1.02)	5.97	1.49	0.55 (1.02)	1.66 (1.46)	1.44 (1.39)	0.88 (117)	0.66 (1.07)	4.64	1.16
5.	Jaggery Solution 10%	1.32 (1.34)	3.77 (2.06)	1.21 (1.30)	0.99 (1.22)	0.66 (1.07)	6.63	1.65	0.66 (1.07)	1.55 (1.43)	1.66 (1.46)	0.99 (1.22)	0.77 (1.12)	4.97	1.24
6.	Molasses 10%	1.66 (1.46)	3.77 (2.06)	1.66 (1.46)	1.33 (1.35)	0.77 (1.12)	7.53	1.88	0.77 (1.12)	2.22 (1.64)	1.77 (1.50)	1.21 (1.30)	0.77 (1.12)	5.97	1.49
7.	Honey Solutions 10%	1.22 (1.30)	3.66 (2.03)	2.1 (1.61)	1.55 (1.43)	0.44 (0.96)	7.75	1.93	0.44 (0.96)	2.21 (1.64)	2.1 (1.61)	1.33 (1.35)	0.99 (1.22)	6.30	1.57
8.	Pomegranate Juice 5%	1.21 (1.30)	2.88 (1.83)	1.1 (1.26)	0.77 (1.12)	0.55 (1.02)	5.30	1.32	0.55 (1.02)	1.21 (1.30)	1.22 (1.30)	0.77 (1.12)	0.66 (1.07)	3.86	0.96
9.	SE+	0.0294	0.0275	0.0342	0.016	0.0145			0.0153	0.0288	0.028	0.0271	0.0114		
10.	CD 5%	0.0891	0.0836	0.1037	0.0486	0.0441			0.0464	0.0873	0.0849	0.0821	0.0347		

*= Figures in the parentheses are transformed $\sqrt{x+0.5}$ values

DBS = Days before spraying,

DAS = Days after spraying

4.3.2 Influence of bee attractant on activity of *Apis cerana indica* on bitter gourd

The observations were recorded on *A. cerana* visitation on Bitter gourd treated with different bee attractants at 10 and 50 per cent of flowering are presented in Table 9.

First spray

A day prior to the application of attractants, bee activity was ranged from 1.21 to 1.88 bees/m^2/min.

A day after the first spray, jaggery solution 10 per cent attracted higher number of bees (4.44 bees/m^2/min) and was significantly superior compared to other treatments. Further this treatment was at par with honey solution 10 per cent (3.55 bees/m^2/min), sugarcane juice 10 per cent(3.33 bees/m^2/min), molasses 10 per cent was next better treatment with 3.1 bees/m^2/min. Least number of bees was recorded in open pollination without spray (1.44 bees/m^2/min).

On 3rd day after first spray, honey solution 10 per cent recorded maximum number of bees (2.99 bees/m^2/min) and found superior over all the treatment. Jaggery solution 10 per cent which was next better treatment which recorded 2.10 bees/m^2/min. Further molasses 10 per cent, sugarcane juice 10 per cent and sugar solution 10 per attracted 1.99, 1.66 and 1.33 bees/m^2/min respectively. Open pollination without spray was inferior over all the treatments as it recorded less number of bees (0.88 bees/m^2/min).

On 5th day after first spray, treatment honey solution 10 per cent was significantly superior to attract the maximum number of bees (1.99 bees/m^2/min) followed by jaggery solution 10 per cent, sugar solution 10 per cent and molasses 10 per cent with 1.33, 1.33 and 1.21 bees/m^2/min, respectively. The next best treatments were sugarcane solution 10 per cent recorded 0.99 bees/m^2/min. Open pollination without spray recorded lowest number of bees (0.77 bees/m^2/min).

On 7th day after first spray no significant difference was observed between different bee attractant treatments. Observations were recorded between 0.66 bees/m^2/min to 0.88 bees/m^2/min.

Overall performance of bee attractants spray atb10 per cent flowering showed that honey solution has highest (2.32 bees/m^2/min) average ability to attract *Apis cerena indica* towards it followed by jaggery solution 10 per cent (2.16 bees/m^2/ min) and molasses 10 per cent (2.04 bees/m^2/min).

Second spray

One day before second spray, the visitation of *A. cerana indica* was in the range of 0.66 to 0.88 bees/m^2/min.

A day after second spray treatment with honey solution 10 per cent (2.44 bees/m^2/min) was significantly superior over all the treatment thereafter molasses 10 per cent (2.33 bees/m^2/min). Jaggery solution 10 per cent and sugarcane juice 10 per cent (1.88 bees/m^2/min) was the next best

Table 9. Influence of bee attractants on activity of *Apis cerana indica* on bitter gourd

Sr. No.	Treatment	Number of bees per square meter per minute													
		1st spray at 10 per cent flowering							2nd spray at 50 per cent flowering						
		1 DBS	1 DAS	3 DAS	5 DAS	7 DAS	Total	Average	1 DBS	1 DAS	3 DAS	5 DAS	7 DAS	Total	Average
1.	Open Pollination	1.55 (1.43)*	1.44 (1.39)	0.88 (1.17)	0.77 (1.12)	0.66 (1..07)	3.75	0.93	0.66 (1.07)	1.65 (1.46)	1.66 (1.46)	0.99 (1.22)	0.99 (1.22)	5.29	1.322
2.	Coconut Water 10%	1.44 (1.39)	2.44 (1.71)	1.1 (1.26)	0.99 (1.22)	0.77 (1.12)	5.3	1.32	0.77 (1.12)	1.77 (1.50)	1.77 (1.50)	0.99 (1.22)	0.99 (1.22)	5.52	1.38
3.	Sugar Solution 10%	1.88 (1.54)	2.88 (1.83)	1.33 (1.35)	1.33 (1.35)	0.66 (1.07)	6.2	1.55	0.55 (1.02)	1.77 (1.50)	2.21 (1.64)	1.11 (1.26)	1 (1.22)	6.09	1.52
4.	Sugarcane Juice 10%	1.55 (1.43)	3.33 (1.95)	1.66 (1.46)	0.99 (1.22)	0.88 (1.17)	6.86	1.71	0.88 (1.17)	1.88 (1.54)	2.1 (1.61)	1.1 (1.26)	0.99 (1.22)	6.07	1.51
5.	Jaggery Solution 10%	1.66 (1.46)	4.44 (2.22)	2.1 (1.61)	1.33 (1.35)	0.77 (1.12)	8.64	2.16	0.77 (1.12)	1.88 (1.54)	2.33 (1.68)	1.22 (1.31)	1.1 (1.26)	6.53	1.63
6.	Molasses 10%	1.21 (1.30)	3.1 (1.89)	1.99 (1.57)	1.21 (1.30)	0.66 (1.07)	8.17	2.04	0.66 (1.07)	2.33 (1.68)	2.88 (1.83)	1.33 (1.35)	0.99 (1.22)	7.53	1.88
7.	Honey Solutions 10%	1.33 (1.35)	3.55 (2.01)	2.99 (1.86)	1.99 (1.57)	0.77 (1.12)	9.3	2.32	0.77 (1.12)	2.44 (1.71)	2.77 (1.80)	1.66 (1.46)	1.1 (1.26)	7.97	1.99
8.	Pomegranate Juice 5%	1.77 (1.50)	2.66 (1.77)	1.1 (1.26)	0.88 (1.17)	0.66 (1.07)	5.3	1.32	0.66 (1.07)	1.77 (1.50)	1.77 (1.50)	0.99 (1.22)	0.99 (1.22)	5.52	1.38
9.	SE +-	0.0269	0.0135	0.022	0.0362	0.0116			0.0121	0.033	0.0409	0.0171	0.015		
10.	CD 5%	0.0817	0.0408	0.0668	0.1099	0.0353			0.0366	0.0999	0.1241	0.0517	NS		

*=Figures in the parentheses are transformed $\sqrt{x+0.5}$ values

DBS = Days before spraying,

DAS = Days after sprayin

treatment and found at par with sugar solution 10 per cent which recorded 1.77 bees/m^2/min. Open pollination without spray found to be least efficient in attracting more number of bees (1.65 bees/m^2/min).

On 3rd day after second spray, plot treated with molasses 10 per cent attracted maximum number of bees (2.88 bees/m^2/min). The next best treatment was honey solution 10 per cent (2.77 bees/m^2/min) followed by jaggery solution 10 per cent (2.33 bees/m^2/min). Rest of the treatments also found superior over open pollination without spray which recorded the least number of bees (1.66 bees/m^2/min).

Similar trend was found in 5th day after second spray, the treatment honey solution 10 per cent (1.66 bees/m^2/min) which was proved to be the best treatment. Molasses 10 per cent, jaggery solution 10 per cent and sugarcane juice 10 per cent was the next better treatment which recorded 1.33, 1.22 and 1.1 bees/m^2/min, respectively.

On 7th day after second spray, the treatment honey solution 10 per cent and jaggery solution 10 per cent (1.10 bees/m^2/min) was successful in attracting highest number of bees. Similarly the rest of the treatments found to be superior over open pollination without spray which recorded least number of bees (0.99 bees/m^2/min).

Overall recorded observations showed that honey solution 10 per cent had highest average ability to attract *Apis cerena species* (1.99 bees/m^2/min) followed by molasses 10 per cent (1.88 bees/m^2/min) and jaggerry solution 10 per cent (1.63 bees/m^2/min).

4.3.3 Influence of bee attractant on activity of *Apis mellifera* on bitter gourd

Data pertaining to the effect of attractant on activity of *A. mellifera* on Bitter gourd is presented in Table 10.

First spray

There was no significant difference in the bee visitation among the various treatments, a day before first spray and it was ranged from 0.88 to 1.10 bees/m^2/min.

One day after first spray, more number of bees (2.22 bees/m^2/min) was attracted in the treatment sugar solution 10 per cent and found to be significantly superior over all the treatments over honey solution 10 per cent, jaggery solution 10 per cent and sugarcane juice 10 per cent (1.88 bees/m^2/min each). Molasses 10 per cent and pomegranate juice 5 per cent were also which recorded 1.66 bees/m^2/min each better treatments over Open pollination without spray recorded the lowest number of bees (0.99 bees/m^2/min).

Table 10. Influence of bee attractants on activity of *Apis mellifera* on bitter gourd

Sr. No.	Treatment	Number of bees per square meter per minute													
		1st spray at 10 per cent flowering							2nd spray at 50 per cent flowering						
		1 DBS	1 DAS	3 DAS	5 DAS	7 DAS	Total	Average	1 DBS	1 DAS	3 DAS	5 DAS	7 DAS	Total	Average
1.	Open Pollination	0.99 (1.22)	0.99 (1.22)	0.77 (1.12)	0.77 (1.12)	0.44 (0.96)	2.97	0.74	0.44 (0.96)	1.66 (1.46)	1.55 (1.43)	0.77 (1.12)	0.77 (1.12)	4.75	1.18
2.	Coconut Water 10%	1 (1.22)	1.44 (1.39)	1.1 (1.26)	0.88 (1.17)	0.44 (0.96)	3.86	0.96	0.44 (0.96)	1.99 (1.57)	1.77 (1.50)	0.77 (1.12)	0.88 (1.17)	5.41	1.35
3.	Sugar Solution 10%	1.1 (1.26)	2.22 (1.64)	1.44 (1.39)	1.1 (1.26)	0.55 (1.02)	5.31	1.32	0.55 (1.02)	2.11 (1.61)	2.1 (1.61)	0.99 (1.22)	0.88 (1.17)	6.08	1.52
4.	Sugarcane Juice 10%	0.88 (1.17)	1.88 (1.54)	1.55 (1.43)	1.1 (1.26)	0.55 (1.02)	5.08	1.27	0.55 (1.02)	2.22 (1.64)	2.1 (1.61)	1.21 (1.30)	0.88 (1.17)	6.41	1.60
5.	Jaggery Solution 10%	1.11 (1.26)	1.88 (1.54)	1.55 (1.43)	1.44 (1.39)	0.55 (1.02)	5.42	1.32	0.55 (1.02)	2.33 (1.68)	2.21 (1.64)	1.11 (1.26)	0.88 (1.17)	6.53	1.63
6.	Molasses 10%	0.88 (1.17)	1.66 (1.46)	1.66 (1.46)	1.1 (1.26)	0.55 (1.02	4.97	1.24	0.55 (1.02)	3.21 (1.92)	2.21 (1.64)	1.33 (1.35)	0.88 (1.17)	7.63	1.90
7.	Honey Solutions 10%	0.88 (1.17)	1.88 (1.54)	2.1 (1.61)	1.77 (1.50)	0.66 (1.07)	6.41	1.60	0.66 (1.07)	2.33 (1.68)	2.32 (1.68)	1.32 (1.35)	1.1 (1.26)	7.09	1.76
8.	Pomegranate Juice 5%	0.88 (1.17)	1.66 (1.46)	1 (1.22)	0.77 (1.12)	0.66 (1.07)	4.09	1.02	0.66 (1.07)	1.99 (1.57)	1.77 (1.50)	0.77 (1.12)	0.77 (1.12)	5.30	1.32
9.	SE +	0.0218	0.0188	0.0207	0.0153	0.0143			0.0157	0.0135	0.0245	0.0275	0.0204		
10.	CD 5%	0.066	0.057	0.0627	0.0463	0.0432			0.0477	0.0409	0.0744	0.0835	0.062		

Figures in the parentheses are transformed $\sqrt{x + 0.5}$ values
DBS = Days before spraying
DAS = Days after spraying

Similarly on 3rd day after first spray, plot treated with honey solution 10 per cent attracted maximum number of bees (2.10 bees/m^2/min). The next better treatment was molasses 10 per cent (1.66 bees/m^2/min) followed by jaggery solution 10 per cent and sugarcane juice 10 per cent with 1.55 bees/m^2/min each. Rest of the treatment also found superior over open pollination without spray which recorded the least number of bees (0.77 bees/m^2/min).

On 5th day after second spray, the treatment honey solution 10 per cent (1.77 bees/m^2/min) proved to be superior among treatments of bee attractants. Jaggery solution 10 per cent was another better treatment followed by sugar solution 10 per cent, molasses 10 per cent and sugarcane juice 10 per cent which attracts 1.44, 1.10, 1.10 and 1.10 bees/m^2/min, respectively. Molasses 10 per cent was the next best treatment which recorded 3.95 bees/m^2/min and found at par with sugarcane juice 10 per cent (3.91 bees/m^2/min).

On 7th day after second spray, the treatment honey solution 10 per cent was successful in attracting highest number of bees (0.66 bees/m^2/min) and it was at par with sugar solution 10 per cent, sugarcane juice 10 per cent, jaggery solution 10 per cent and molasses 10 per cent having 0.55 bees/m^2/min each which were superior over open pollination without spray which attracted minimum number of bees (0.44 bees/m^2/min).

Second spray

The visitation of *A. mellifera* on one day before second spray was in the range of 0.44 to 0.66 bees/m^2/min.

A day after the second spray, molasses 10 per cent attracted higher number of bees (3.21 bees/m^2/min). Honey solution 10 per cent, jaggery solution 10 per cent (2.33 bees/m^2/min) and sugarcane juice 10 per cent were next better treatments attracted 2.33, 2.33 and 2.22 bees/m^2/min respectively. The least number of bees was recorded in open pollination without spray (1.66 bees/m^2/min).

Similarly on 3rd day after second spray, honey solution 10 per cent recorded maximum number of bees (2.32 bees/m^2/min) and found superior over all the treatment. The next best treatments were molasses 10 per cent and jaggerry solution 10 per cent which was recorded 2.21 bees/m^2/min each. Sugarcane juice 10 per cent, and sugar solution 10 per cent which recorded 2.10 bees/m^2/min each. Open pollination without spray was inferior over all the treatments as it recorded less number of bees (1.55 bees/m^2/min).

On 5th day after second spray, treatment molasses 10 per cent and honey solution 10 per cent was significantly superior to attract the maximum number of bees (1.33 and 1.32 bees/m^2/min respectively) followed by sugarcane juice 10 per cent and sugar solution 10 per cent with 1.21 and 0.99 bees/m^2/min respectively. The treatment open pollination without spray recorded lowest number of bees (0.77 bees/m^2/min).

On 7th day after second spray, the plots sprayed with honey solution 10 per cent attract the maximum number of bees (1.10 bees/m^2/min) and found at par with sugar solution 10 per cent jaggery solution 10 per cent, molasses 10 per cent and sugarcane juice 10 per cent (0.88 bees/m^2/min) and found significantly superior over open pollination without spray which recorded least number of bees(0.77 bees/m^2/min).

Overall observations showed that molasses 10 per cent was having highest bee attractant ability over other bee attractants with average of 1.90 bees/m^2/min. Thereafter honey solution 10 per cent, jaggery solution and sugarcane juice having average ability of 1.76, 1.63 and 1.60 bees / m^2 / min. respectively.

4.4 Effect of bee pollination on seed and yield contributing characters of Bitter gourd

Data on effect of bee pollination on seed yield and yield contributing characters of Bitter gourd *viz.*, number of fruits/plant, number of seeds/fruit, per cent wrinkled seeds/fruit, weight of 100 seeds, yield of 5 plants (kg/plant) and net yield (qtl/ha) are presented in Table 11 and depicted in figure no.7 to 11.

1. Number of fruits per plant

All the treatments which received attractants in which Honey solution 10 per cent which recorded 35.88 fruits per plant was superior followed by jaggery solution 10 per cent, molasses 10 per cent, sugar solution 10 per cent and sugarcane juice 10 per cent which recorded 34.21, 33.42, 32.51 and 32.47 fruits per plant, respectively. Pollination without insect recorded lowest number of fruits (0.16 fruits / plant) and open pollination has reported 30.2 fruits/plant. The results are plotted in figure no. 7.

2. Number of seeds per fruit

The plot sprayed with honey solution 10 per cent was found significantly superior over all the treatments by recording highest number of seeds/fruit (41.40 seeds/fruit) which resulted in 30.59 and 53.33 per cent increase over open pollination without spray and PWI respectively. The next better treatment was jaggery solution 10 per cent (37.50 seeds/fruit) with an increase of 18.29 and 38.88 per cent over open pollination and PWI respectively and which found at par with each other.

Table 11. Effect of bees pollination on yield and seed contributing characters of bitter gourd

Sr. No.	Treatment	No. of fruits per plant	No. of seeds/Fruits	Per cent increase over		Per cent wrinkled seed	Per cent decrease over		Weight of 100 seeds in gm	Per cent increase over		Yield of 5 plants in kg	Per cent increase over		Yield per ha(Qtl)	Per cent increase over	
				OP	PWI		OP	PWI		OP	PWI		OP	PWI		OP	PWI
1.	Open Pollination	30.2	31.7			2.83			25.96			1.24			2.728		
2.	Pollination Without Insects	0.16	27			3.05			24.5			0.52			1.144		
3.	Coconut Water 10%	31.34	32.7	3.15	21.11	2.14	24.38	29.83	26.59	2.42	8.53	1.36	9.67	161.53	2.992	9.67	161.53
4.	Sugar Solution 10%	32.51	34.4	8.51	27.4	2.32	18.02	23.93	26.98	3.92	10.12	1.5	20.96	188.46	3.300	20.96	188.46
5.	Sugarcane Juice 10%	32.47	34.8	9.77	28.88	2.29	19.08	24.91	27.03	4.12	10.32	1.52	22.58	192.3	3.344	22.58	192.30
6.	Jaggery solution10%	34.21	37.5	18.29	38.88	1.86	34.27	39.05	27.2	4.77	11.02	1.74	40.32	234.61	3.828	40.32	234.61
7.	Molasses Solution 10%	33.42	36.2	14.19	34.07	1.93	31.8	36.72	26.91	3.65	9.83	1.62	30.64	211.53	3.564	30.64	211.53
8.	Honey Solution 10%	35.88	41.4	30.59	53.33	1.2	57.59	60.65	29.57	13.9	20.69	2.19	76.61	321.15	4.818	76.61	321.15
9.	Pomegranate Juice 5%	31.78	32.9	3.78	21.85	2.15	24.02	29.5	26.92	3.69	9.87	1.4	12.9	169.23	3.080	12.90	169.23
10.	SE +	0.3085	0.8692			0.1988			0.443			0.0301			0.0433		
11.	CD 5%	0.925	2.6059			0.596			1.3282			0.0903			0.1297		

OP = Open Pollination

PWI = Pollination Without Insect

The treatments viz. molasses 10 per cent, sugarcane juice 10 per cent and sugar solution 10 per cent were found superior over open pollination without spray and PWI by recording 36.20, and 34.80 and 34.40 seeds/fruit respectively.

The remaining two treatments recorded least number of seeds/fruit viz., open pollination without spray and PWI recorded 27.00 and 31.70 seeds/fruits respectively as depicted in figure no.8.

These results clearly indicated that application of attractants are beneficial and has positive effect in increasing the number of seeds/fruits. This was due to increased visitation of bees that caused the well distribution of pollen thus it resulted in the effective cross pollination and better seed setting.

3. Per cent of wrinkled seeds/fruit

According to the data depicted in figure no.9, treatment with honey solution 10 per cent noticed least number of 1.20 wrinkled seed/fruit and found superior over rest of treatments. This resulted in maximum of 57.59 and 60.65 per cent decreased over open pollination without spray and PWI, respectively and which was followed by jaggery solution 10 per cent (1.86 wrinkled seeds/fruit) with 34.27 and 39.05 per cent decrease over open pollination without spray and PWI respectively.

The next better treatments were molasses 10 per cent (1.93 wrinkled seeds/fruit) with 31.80 and 36.72 and coconut water 10 per cent (2.14 wrinkled seeds/fruit) with recording 24.38 and 29.83 per cent decrease over open pollination without spray and PWI respectively.

Pomegranate juice 5 per (2.15 wrinkled seeds/fruit), sugarcane juice 10 per cent (2.29 wrinkled seeds/fruit) and sugar solution 10 per cent (2.32 wrinkled seeds/fruit) and were at par with each other and significantly superior over the treatment viz., PWI and open pollination without spray.

However, the treatment PWI recorded maximum number of wrinkled seeds/fruit (3.05) and was significantly inferior to all the treatments. Open pollinated plot without any spray recorded 2.83 wrinkled seeds/fruit.

4. Test weight (weight of 100 seeds)

The open pollinated crop which received honey solution 10 per cent (29.57 gm/100 seeds) with an increase of 13.90 and 20.69 per cent over open pollination without spray and PWI, respectively. Jaggery solution 10 per cent (27.20 gm/100 seeds) and sugarcane juice 10 per cent (27.03 gm/100 seeds) were the next better treatment which showed (4.77 and 11.02) and (4.12 and 10.32) per cent increase over open pollination without spray and PWI, respectively.

The plot sprayed with sugar solution 10 per cent was recorded the 26.98 gm per 100 seed which was followed by molasses 10 per cent recording 26.91gm/100 seeds weight and were significantly superior over open pollination without spray and PWI which recorded least test weight of 25.96 and 24.50gm/100 seeds respectively as depicted in figure no.10.

5. Yield of five plant in kg

As depicted in figure no.11, the highest seed yield per 5 plants was recorded in treatment with honey solution 10 per cent (2.19 kg) followed by jaggery solution 10 per cent(1.74 kg) and showed (76.61 and 321.15) and (40.32 and 234.61) per cent increase over open pollination without spray and PWI plot. Molasses 10 per cent (1.62 kg) was next best treatment. Sugarcane juice 10 per cent (1.52 kg) and sugar solution 10 per cent (1.50 kg) respectively which were independently superior over remaining treatments.

The least seed yield of 5 plants 1.24 kg and 0.52 kg were recorded in treatment open pollination without spray and PWI, respectively which proved significantly inferior to all other treatments.

These results indicated that application of attractants could increase the yield due to increase in activity of the pollinators.

6. Seed Yield/ha

The maximum seed yield per ha was recorded in plot which received honey solution 10 per cent (4.818 q/ha) and which was increase with 76.61 and 321.15 per cent over open pollination without spray and PWI respectively and found significantly superior over rest of the treatments.

Next better treatment was the jaggery solution 10 per cent (3.828 q/ha) with increase of 40.32 and 234.61 per cent over open pollinated crop without spray and PWI and it was at par with molasses 10 per cent (3.564 q/ha).

The least yield of 1.144 q/ha was recorded in treatment PWI which proved significantly inferior to all other treatments (depicted in figure no.12.)

5. SUMMARY AND CONCLUSION

The investigation entitled "Studies on role of honey bees as pollinators on seed production of Bitter gourd (*Momardica charantia* L.)" was carried out during *Rabi* season of the year 2016. An experiment was conducted during *Rabi* season of the year 2016 at All India Coordinated Research Project on Vegetable Crops, Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri. Dist. Ahmednagar (Maharashtra) to investigate the effect of bee attractants on bee activity in Bitter gourd and effect of bees pollination on seed yield and yield contributing characters of Bitter gourd are summarized below.

5.1 Summary

5.1.1 Foraging activity of honey bees on Bitter gourd

The intensity of *A. cerana, A. dorsata* and *A.mellifera* reached at its peak at 10.00 to 12.00 hrs. When comparison made between different weeks during flowering, the activity of *A. cerana, A. dorsata* and *A. mellifera* was maximum in 1st week.

Foraging activity of *A. dorsata* started at 08.00 hrs with an average of 0.50 bees/m^2/min and gradually increased, attained peak at 12.00 hrs (2.30 bees/m^2/min). Similarly foraging activity of *A. mellifera* was maximum at 12.00 hrs (1.70 bees/m^2/min). Foraging activity of *A. cerana indica* was observed from 08.00 to 18.00 hrs which reached at peak at 10.00 hrs (2.15 bees/m^2/min) and was higher than other pollinator species. Similar trend was also observed in other pollinators and they attained peak activity at 12.00 hrs (4.15 bees/m^2/min).

A. cerena visited the maximum number of flowers per minute with 1.19 flower/min and found to be more efficient pollinator followed by *A. dorsata* (1.02 flower/min) and *A. mellifera* (0.85 flower/min).

5.1.2 Effect of bee attractants on activity of honey bees on Bitter gourd

Spraying of bee attractants *i. e.* Honey solution 10 percent, molasses 10 per cent and jaggery solution 10 per cent attracted maximum number of *A. dorsata* up to 5 days after first spray (10% flowering). After second spray, the effectiveness of attractants like Honey solution 10 percent, molasses 10 per cent and jaggery solution 10 per cent was maximum on 1st day after spray (50% flowering). Sugar solution 10 per cent and sugarcane juice 10 per cent were the next best treatment in attracting more number of bees and open pollination without spray had lower level of response to honey bees.

As regard *A. cerana* honey solution 10 per cent, Jaggery solution 10 per cent and molasses 10 per cent were efficient in attracting more bees up to 5th day of first spray (10% flowering), however after 2nd spray their effect of honey solution 10 per cent, molasses 10 per cent and jaggery solution 10 per cent remained up to 7th day. Sugarcane juice 10 per cent and sugar solution 10 per cent were also effective in attracting more number of bees compared to open pollination without spray. Pomegranate juice 10 per cent and coconut water 10 per cent were the next better treatments over open pollination without spray which was attracted less number of bees.

In case of *A. mellifera* spraying of honey solution 10 per cent, jaggery solution 10 per cent and molasses 10 per cent were attracted more bees up to 7th day of both first spray and second spray. Sugar solution 10 per cent, sugarcane juice 10 per cent, pomegranate juice 10 per cent and coconut water 10 per cent were the next better treatments over open pollination without spray which was attracted less number of bees.

5.1.3 Effect of bee pollination on seed and yield contributing characters of Bitter gourd

Spraying of honey solution 10 per cent, jaggery solution 10 per cent, sugar solution 10 per cent, sugarcane juice 10 per cent, molasses 10 per cent, pomegranate juice and coconut water 10 per cent found significantly superior in enhancing quantitative parameters of Bitter gourd seed yield contributing characters.

The maximum number of seeds (41.4 seeds/fruit) were recorded in the treatment honey solution 10 per cent as against open pollination without spray (31.7 seeds/fruit) and PWI (27.0 seeds/fruit) which resulted in increase of 30.59 and 53.33 per cent over open pollination without spray and PWI respectively.

Lowest per cent of wrinkled seeds/fruit (1.20 %) recorded in the treatment with honey solution 10 per cent as against open pollination without spray (2.83 %) and PWI (3.05%). Higher test weight of 29.57 g in honey solution 10 per cent and 27.20 g in jaggery solution 10 per cent against 25.96 and 24.50 g in open pollination without any spray and PWI respectively.

The crop sprayed with honey solution 10 per cent recorded highest yield of 5 plants from plot of 2.19 kg/five plants, as against open pollination without spray (1.24 kg/five plants) and PWI (0.52 kg/five plants) by increasing 76.61 and 321.15 per cent over open pollination without spray and PWI respectively. The next better treatment was jaggery solution 10 per cent (1.74 kg/five plants).

Similarly the highest net yield (4.818 q/ha) was received in the treatment honey solution 10 per cent as against open pollination without spray (2.728 q/ha) and PWI (1.144 q/ha).

Next best treatments were jaggery solution 10 per cent and molasses 10 per cent which recorded 3.828 and 3.564 q/ha respectively.

5.2 Conclusion

On the basis of results obtained during the course of present investigation, it could be concluded that:

- ✓ *Apis cerena indica* found to be most abundant pollinator in Bitter gourd ecosystem (31.57%) followed by *Apis dorsata* (26.31%) and *Apis mellifera* (22.36%).
- ✓ The most favorable time 10:00 am to 12:00 pm was found to be best for foraging activity of *A. cerana indica, A. dorsata, A. mellifera* and other pollinators (2.15, 2.30, 1.70 and 4.15 bees/m^2/min) respectively.
- ✓ Among the bee attractants honey solution 10 per cent found to be the superior treatment in attracting higher number of *A. dorsata*, *A. cerana indica*, *A. mellifera* and other pollinators followed by 10% molasses solution and 10 per cent jaggery solution.
- ✓ Irrespective of treatments, the peak pollinator activity was found on 1st day after spraying of bee attractants.
- ✓ The higher yield contributing characters like number of fruits (35.88 fruit/plant), number of seeds (41.4 seeds/fruit), test weight (29.57 g/100 seeds) and total yield (4.818 q/ha) were recorded in 10 per cent honey solution and found to be the best attractant followed by 10 per cent jaggary solution and 10 per cent molasses solution.
- ✓ In contrary lowest yield and yield related attributes recorded in pollination without insects and open pollination.

Future line of work

1. Bee attractants like honey solution, molasses, jaggery solution, sugar solution, sugarcane juice, pomegranate juice and coconut water should be tested for efficacy by conducting large field scale experiments.
2. There is a need to study the influence of indigenous bee attractants on improvement of quality parameters of other cross pollinated crops like bitter gourd.

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7. VITAE

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MASTER OF SCIENCE (AGRICULTURE)
IN
AGRICULTURAL ENTOMOLOGY

2018

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Major field

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Educational

- Passed S.S.C. Examination from New English school, Dhotre Bk. Tal. Parner, Dist. Ahmednagar with Distinction.
- Passed H.S.C. examination From New Arts, Commerce and Science College, Ahmednagar with distinction.
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