ROLE OF HONEY BEES IN SEED PRODUCTION OF SUNFLOWER, *Helianthus annus* L. AND ONION, *Allium cepa* L.

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Role of honey bees in seed production of sunflower, *Helianthus annus* L. and onion, *Allium cepa* L.

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ABSTRACT

The study on role of honey bees on seed production was carried out at Department of Entomology, B. A. College of Agriculture, Anand Agricultural University, Anand (Gujarat). Studies on foraging and seasonal activities of honey bees were carried out for sunflower at Agronomy farm, Anand Agricultural University, Anand during *Kharif*, 2017 and *rabi*, 2017-18 and for onion at Main Vegetable Research Station, AAU, Anand during *rabi*, 2017 and 2018.

Sunflower and onion possessing characters of heavy and sticky pollen grains. Hence, pollinating agents are needed for better quality and quantity of crop. The data recorded higher bee visits on first (3.22 to 3.83 bees/ 5 capitula/ 2 minutes) and third day (3.34 to 3.78) after both the sprays in *kharif* and *rabi*, 2017-18 in sunflower in the treatments of sugar and jaggery solution (5%). However, after three days of sprays, the influences of both the sprays declined.

Various quantitative characters of sunflower during *kharif*, 2017 indicated that the treatment of jaggery solution (5%) was found superior by showing head diameter (36.25 cm), head weight (1670 gm), number of filled seeds per head (1975), weight of thousand seeds (65 gm), seed weight per head (640 gm), total number of seeds/ head (1985) and yield (1530 kg/ ha) followed by treatment of sugar solution (5%) with head diameter (34.75 cm), head weight (1650 gm), number of filled seeds per head (1930), weight of thousand seeds (60 gm), seed weight per head (610 gm), total number of seeds/ head (1980) and yield (1525 kg/ ha). Various qualitative characters showed that the treatment of jaggery solution (5%) was found superior by indicating higher oil per cent (42%) while more germination (97%) and seed setting (97%) were found in the treatment of one framed *Apis mellifera* L. colony covered with net. Minimum wrinkled seed (10%) was found in the treatment of sugar solution (5%). During *rabi*, 2017-18 various quantitative characters indicated that the treatment of jaggery solution (5%) was found superior by showing head diameter (39.75 cm), head weight (1720 gm), number of filled seeds per head (1965), weight of thousand seeds (68 gm), seed weight per head (625 gm), total number of seeds/ head (1990) and yield (1610 kg/ ha) followed by treatment of sugar solution (5%) with head diameter (38.25 cm), head weight (1680 gm), number of filled seeds per head (1950), weight of thousand seeds (62 gm), seed weight per head (630 gm), total number of seeds/ head (1995) and yield (1640 kg/ ha). Various qualitative characters showed lower wrinkled seeds (11%) in the treatment of jaggery solution (5%), more oil per cent in the treatment of sugar solution (5%) and maximum germination (96%) and

seed setting (98%) in the treatment of one framed *A. mellifera* colony covered with net. Minimum wrinkled seed (11%) were found in the treatment of jaggery solution (5%). The data showed more or less similar trend in the treatments of a colony of *Trigona* sp. covered with net and open pollination.

Bee visits were maximum on first day (3.34 to 3.70 bees/ m^2/ 2 minutes) and third day (2.96 to 3.30) after sprays during *rabi*, 2017 and *rabi*, 2018 in the treatments of sugar and jaggery five per cent spray solution. Although, after three days of sprays, the influences of both the sprays declined.

Various quantitative characters of onion during *rabi*, 2017 indicated that the treatment of sugar solution (5%) was found superior by showing umbel weight (382.50 g/ umbel), weight of thousand seeds (5.85 gm), total number of seeds/umbel (4930) and total seed yield (1425.50 kg/ ha) followed by treatment of jaggery solution (5%) by showing umbel weight (365 g/ umbel), weight of thousand seeds (5.25 gm), total number of seeds/umbel (4820) and total seed yield (1420.00 kg/ ha). Among the various qualitative characters, treatment of sugar solution (5%) was found superior by showing wrinkled seeds (11.00%) and gemination (91%) followed by treatment of jaggery solution (5%) by indicating wrinkled seeds (10.75%) and gemination (89.25%). Various quantitative characters of onion during *rabi*, 2018 treatment of sugar solution (5%) was found superior by showing umbel weight (395.00 g/ umbel), weight of thousand seeds (5.55 gm), total number of seeds/umbel (4835) and total seed yield (1432.50 kg/ ha) followed by treatment of jaggery solution (5%) by indicating umbel weight (382 g/ umbel), weight of thousand seeds (5.78 gm), total number of seeds/umbel (4865) and total seed yield (1440.00 kg/ ha). So far, various qualitative characters indicated that the treatment of sugar solution (5%) was found superior by showing wrinkled seeds (11.75%) and gemination (91.75%) followed by treatment of jaggery solution (5%) wih wrinkled seeds (11.25%) and gemination (90.35%). The data showed more or less similar trend in the treatments of a colony of *Trigona* sp. covered with net and open pollination.

Visits of number of bees per 2 min per sq.m. area started from 08.00 hrs. Seasonal activities of honey bees were reached to its peak on 10.00 to 12.00 hrs (1.75 to 2.25 bees/ m^2/ two minute) during the months of November and December in sunflower crop. These activities showed decline as time passed and lower activities were found at 16.00 to 18.00 hrs. Same trends was found in onion during *rabi*, 2017 and *rabi*, 2018. Number of bee visits showed significant positive correlation with bright sunshine hour and minimum temperature, morning relative humidity and evening relative humidity, while negative correlation with wind speed and highly negative correlation with maximum temperature. These results indicated that bee visits were highly fluctuated with weather conditions like temperature, wind speed and relative humidity. The results clearly proved that the augmentation of honey bee colonies in the sunflower and onion field during flowering would be advisable to improve the qualitative and quantitative yield parameters. The results also indicated higher production of seed yield with introduction of colonies of honey bees with sugar and jaggery like phagostimulants which attracted more number of bees. In nutshell, honey bees are more attracted towards sugar and jaggery.

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C E R T I F I C A T E

This is to certify that the thesis entitled **"Role of honey bees in seed production of sunflower, *Helianthus annus* L. and onion, *Allium cepa* L."** submitted by **MS. TANVIBEN B. KAPADIYA** in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE** in **AGRICULTURAL ENTOMOLOGY** of the Anand Agricultural University is a record of bonafide research work carried out by him under my personal guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

Place : Anand
Date : / 06 /2018

(C. C. Patel)
Major Guide

DECLARATION

This is to declare that the whole of the research work reported here in the thesis for the partial fulfillment of the requirements for the award of the degree of Master of Science in Agricultural Entomology is the results of investigation done by me under the direct guidance and supervision of Dr. C. C. Patel, Research Scientist, Department of Entomology, Anand Agricultural University, Anand and no part of the research work has been submitted for any other degree so far.

Place : Anand **(TANVI B. KAPADIYA)**
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Life is not so short but that there is always time enough for courtesy

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Place: Anand **(TANVI B. KAPADIYA)**

Date: / 06/2018

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LIST OF ABBREVIATIONS

AAU	Anand Agricultural University
&	And
Anon.	Anonymous
Av.	Average
BACA	B. A. College of Agriculture
cm	Centimetre
C.V.	Coefficient of Variation
r	Correlation coefficient
C.D.	Critical difference
DAS	Days after spray
°C	Degree Celsius
EC	Emulsifiable concentrate
=	Equal to
et al	Et allii; and others
etc.	Etcetera
fig.	Figure
g	Gram
>	Greater than
h / hr	Hours
ha	Hectare
i.e.	That is
kg	Kilogram
l	Litre
m	Metre
ml	Millilitre
NS	Not significant
No.	Number
%	Percent
q	Quintal
RBD	Randomized Block Design
m^2	Square metre
S.Em. ±	Standard Error of mean
SMW	Standard Meteorological Week
viz.	Videlicet, Namely

CONTENTS

1. INTRODUCTION

Sunflower (*Helianthus annus* L.) belongs to the Asteraceae family is an important oil seed crop after soybean in world and it also holds second position in India. It is also known as 'Surajmukhi'. The large flower head is actually an inflorescence or composite flower made up of two kinds of tiny florets. A single flower has up to two thousand disc florets each with the potential to develop into a seed. The seed contains 35-40 percentage good quality oil. Sunflower oil is used for edible purposes which is a rich source of linoleic acid (66%) helps in reducing cholesterol in the coronary arteries of the heart. The oil is used for manufacturing hydrogenated oil, soaps and cosmetics. Its cakes contain 40-44% high quality protein and is ideally suited for poultry and livestock. The crop has great promise because of its short duration, photo and thermal insensitivity as well as wider adaptability and drought tolerance characteristics. Moreover, all these characteristics lead to grow the crop in any season with good yield. Sunflower is cultivated globally on 21.48 million ha area with production of 26.47 million tonnes in recent times (Anon., 2015). Its cultivation is mainly concentrated in Europe particularly Russian Federation, Argentina, Ukraine *etc*. Sunflower, being a new oilseed crop in India (introduced in 1969) is mainly grown in Karnataka, Maharashtra, Andhra Pradesh and Gujarat.

It can be grown in rotation with several crops. However, raising sunflower after sunflower should be discouraged because of builded up of insect-pests (monocropping). Some of the important crop rotations are like Pigeon pea (early)-sunflower, Maize-sunflower, Maize-potato-sunflower, Rice-sunflower, Maize-toria-sunflower and ratoon sugarcane-sunflower. These crop rotations become more beneficial if pollinations are done by honey bees.

Seeds of sunflower contain 35-40 per cent oil (Furgala, 1954 and Free, 1963). There are over 50 species of genus *Helianthus*. Of which only 2 species, a diploid annual *H. annuus* (2n=34) and hexaploid perennial *H. tubrorus* (2n=102) are cultivatable species. The former is grown as an oilseed crop, while the later as a feed crop for its oil. Sunflower is self-incompatible crop and highly depends on insects mainly bees for pollination and seed-setting, it must be ensured that adequate pollinators are present in field for pollen movement and seed-setting. Lack of adequate pollinators results in 'chaffy' and partially filled seeds, causing reduction in yield.

Hence, honey bees are highly essential for increasing pollination and thereby increase in yield.

According to Free (1964), the importance of honey bees in the production of sunflower (*Helianthus annus* L.) seeds has been the subject of numerous studies. Honey bee (*Apis mellifera* L.) pollination increased the seed yield by 30 per cent and oil content by more than 6 per cent in sunflower (Furgala *et al.,* 1979). Bees have many traits like numerous body hairs, foraging behavior and feeding habits which make them good pollinators. Among these, feeding habit is one of the most important phenomena of honey bees because most of the other insects just feed on nectar and pollen but do not collect these pollen grains and in this manner, they may not be reliable although they supplement bees in pollination (Free, 1993). Hoffman and Chambers (2006) reported the importance of bees in pollination of sunflower crop.

Sunflower (*Helianthus annus* L.) is an allogamic plant which needs insects on flowering especially the honey bees for pollination. Among insects, honey bees are the most important insects in the sunflower pollination process. Unlike other insects that visit flowers only for their own food, bees visit a greater number of flowers to fulfill the needs of their colony. Individual sunflower florets are rarely self-pollinated with sticky heavy pollen and need pollen transferred to them from other florets which can be done by using honey bees (Muller *et al.,* 2006).

Jadhav *et al.* (2011) reported that insects played major role in pollinating sunflower and increased its yield and also studied relative abundance of insect visitors to sunflower capitula of which *Apis* sp. constitutes 88.85 per cent that indicated the dominance of hymenopterans among other sunflower pollinators. According to Abrol (2012), cross pollination of entomophilous crops by honey bees is considered as one of the effective and cheapest methods for triggering the crop yield both qualitatively and quantitatively. The average yield of sunflower in India is 696 kg/ha and it is far less than the world's average of 1322 kg/ha (Anon., 2015).

Sunflower "whole seed" are sold as a snack food after roasting in ovens with or without addition of salt. It is also sold as food for birds and can be used directly in cooking and salads. Its oil extracted from the seeds is used for cooking as a carrier oil and to produce margarine and bio-diesel as it is cheaper than olive oil. The cake

remaining after the seeds can be used as a livestock feed. Sunflowers may also be used to extract toxic ingredients from soil such as lead, arsenic and uranium (Anon., 2017b).

A global review of major vegetables showed that onion ranks second after tomato in area and production of seed. Approximately, 36 million tones onion are produced on 2-5 million ha globally. India is second in the world for onion production, grows onion in approximately 8, 00,000 ha with an average productivity of 10 tones/ ha. It is regarded as a highly export oriented crop and earns valuable foreign exchange for the country (FAO, 2008).

Onion being protandrous flowering crop requires cross pollination and for that it is necessary to increase honey bee visit. Any material to increase the honey bee visits to specific crops would be of great practical value to harvest the benefits of cross pollination. Bee pollination not only increases the seed yield of various crops but also improves its quality. Honey bees are highly efficient as primary pollinators of entomophilous crops like onion (Mupade *et al.,* 2009). According to Banik (1990), contribution for pollination by wind was 10%, by other pollinators 3% and by honey bees 87% in onion while hand pollination is very cumbersome job in onion. It is believed that factors such as continuous use of pesticides and decline in natural habitats to some extent are responsible for decreasing the availability of the natural insect pollinators. So, to obtain optimum seed yield, seed producers not only should be aware of the effect of pollinating insects and their efficiency in any given area but also employ the efficient insect pollinators.

In seed crop of onion (*Allium cepa* L.), the inflorescence of onion is an umbel. The onion flower is largely protandrous. The flowers are borned in simple umbel at the apex of a floral stem which is a commonly hollow when mature. The number of flowers per umbel may be as many as 50 to 2000 depending upon the variety. The flowers are white or bluish. The anthers of inner whorls dehiscence first and all the pollen being shed over in a period of two to three days. Onion is highly cross-pollinated crop due to its protandry character. Insects are required to transport the heavy and sticky pollen grains from one flower to another flower in onion. Anther dehiscence occurs in between 5 to 9 am and anthesis starts at 7 am and therefore, honey bees are the most efficient pollinator among different insect pollinators, out of which *A. cerana, A. mellifera, A. dorsata, A. florea* and *Trigona* spp. are highly useful (Patil *et al*., 2010).

The major onion producing states in our country are Maharashtra, Karnataka, Madhya Pradesh, Gujarat, Bihar, Andhra Pradesh, Rajasthan, Haryana and Tamil Nadu. Maharashtra ranks first in onion production with a share of 27.72 per cent. The average seed production of onion in Gujarat is 43.40 MT from area of 57.60 ha (Anon., 2016). The geographic origin of the onion is uncertain because the wild onion is extinct and ancient records of using onions are span western and eastern Asia (Anon., 2017a).

Keeping in view the importance of the major role of honey bee in pollination and yield increasing attributes, present investigation was carried out during 2017 and 2018 at Anand Agricultural University, Anand with following objectives :

1. To determine the pollination efficiency of honey bees based on qualitative and quantitative characters in sunflower and onion crops
2. Seasonal activities of *Apis mellifera* L. and *Trigona* sp.

2. REVIEW OF LITERATURE

Pollination by honey bees are essential for the production of many crops because proper pollination by honey bees are often closely associated with better quality of fruits, vegetables and seeds. However, many crops still experience inadequate pollination due to lacking of healthy pollen grains or absence of other pollinating agents *viz.,* honey bees. Therefore, resulting in reduction in yields, occasional crop failures and lower crop quality. Several scientists have estimated the value of insect pollinated crops that are highly dependent on honey bees under various cropping systems. Among different pollinating agents, insects make a considerable contribution to increase crop production. Up to 90% of all flowering plants species rely on pollination by insects such as bees.

Scanty information on honey bees pollination and efficacy of various bee attractants is available in the literature therefore related review has been reviewed and presented as under.

2.1 Effect of bees pollination in seed production and other related attributes

Mahmood and Furgula (1983) reported that 25 sunflower cultivars were found with higher seed oil content when pollinated by honey bees (*Apis* spp.). A considerable increase in oil content in niger seeds due to bee pollination was reported by Kulkarni and Dhanorkar (1998). Lingappa *et al*. (1999) noted increase in seedling vigour of safflower due to various species of bee pollination. Malerbo-souza *et al.* (2004) conducted an experiment in Italy on various bee attractants and reported that eugenol, citronil and geraniol and lemon grass extract were found the most effective for attracting bees in sweet orange.

Onion seed production has received increased attention recently and the use of honey bees in seed production is well established. Honey bees were found to have a key role in increasing the seed production and improving quality of onion, *Allium cepa* L. cultivar *Valencia*. (Yucel and Duman, 2005).

Among honey bees, *A. mellifera* was the most efficient pollinator as it increased the yield of sunflower as compared to other pollinators (Nderitu *et al*. 2008 and Kumar and Singh, 2005). Furthermore, the mean seeds weight per head (27.65 g and 26.88 g) was also reported higher in open and honey bee pollinated system and it was 162.3 and 155 per cent higher than the control, respectively in sunflower crop. According to Pateel and

Sattagi (2007), treatment of sugar and jaggery solution 10 per cent were efficient in attracting more bees up to third day after first, second and third spray, whereas their activities decreased at fifth day of first, second and third spray. Ten per cent solution of either jaggery or sugar were found best attractants on cucumber (*Cucumis salivas* L.*)* crop at Dharwad.

Mehmet *et al.* (2009) reported that the use of honey bees for sunflower hybrid seed production improved seed set ratio, thousands seed weight, number of filled seed per head and seed yield per head. They reported that pollination in cages without honey bees produced 93-94% less number of filled seeds per head as compared pollination by hand or by honey bees and also in the increased production of sunflower seed in area with introduction of honey bees as compared to areas without bees and also increased yields due to bee pollination in different oil seed crops *viz*., sunflower.

Mupade *et al.* (2009) studied the effect of honey bee pollination on qualitative characters of onion and showed that about 1000 seed weight was 7.1 g in the treatment of one colony of *A. florea* which was recorded highest treatment. The next effective treatment was four framed colony *A. cerana indica* (6.6 g) followed by two framed colony of *A. mellifera* and open pollination treatment (6.2 g and 5.5 g) which were at par with each other.

Oz *et al.* (2009) studied that pollination by honey bees in seed production of sunflower hybrid improved seed set ratio, hundred seed weight, number of filled seed per head and seed yield per head.

Patil *et al*. (2010) conducted an experiment to study the influence of bee attractants on bee visition of *Apis dorsata* L. and *Trigona sp*. on onion (*Allium cepa* L.) at Parbhani. They revealed that a day before the first spray, the number of bees visiting the onion flower ranged from 1.66 to 2.50 bees/m^2/min and did not differ significantly among the treatments. However, the following a day after the first spray, Bee-Q (15 g/lit) attracted the higher number of bees 5.17 bees/m^2/min. *Trigona* sp. treatment with Bee-Q (15 g/lit) was significantly superior in attracting more number of bees 4.00 bees /m^2 / min and was at par with Bee-Q (12.5 g/lit), Bee-Q (10 g/lit), sugar syrup 5 per cent and molasses 10 per cent recorded (3.83, 3.67, 3.67 and 3.60 bees/m^2/min) on 1st day after 1st spray. Open pollination without spray recorded the lowest number of bees (2.30 bees/m^2/min).

Rajasri *et al.* (2012) studied the role of honey bees on pollination, seed setting and seed quality of hybrid sunflower and reported that the seed setting percentage and seed yield were significantly increased when the honey bees (*Apis* spp.) when compared with open pollination. The yields were drastically reduced when the crop was covered with insect proof net. In addition to this, increasing in the seedling vigour, germination (%), oil content and quality of seed were observed.

Mortaza *et al*. (2013) studied effects of insect pollinators on quality and quantity of onion seeds and revealed that the absence of insect pollinators during the flowering period of onion caused substantial reduction on seed number and seed weight per umbel. Also, seeds from free pollination flowers showed higher germination capacity than those isolated from insect visitors.

As per the report of Bezabih and Gebretsadikan (2014), the seed yield was increased by 41.2 per cent, 1000 seeds weight by 25 per cent and germination percentage by 68 per cent due to pollination by honey bees in onion.

Krishna *et al.* (2014) studied the pollination efficiency of honey bees in sunflower (*Helianthus annuus* L.) and reported that the seeds/capitulam (1278), thousand seeds weight (47.3 g) and per cent wrinkled seeds (8.2) were maximum in six framed *A. mellifera* pollinated crop followed by one colony of *A. florea* pollinated crop and also noted that germination percentage in six framed *A. mellifera* pollinated crop was statistically at par with one colony of *A. florae* pollinated crop but the germination was significantly higher in six framed *A. mellifera* (94.3 per cent) followed by open pollination (93.5 per cent) in sunflower crop.

Jayaramappa and Bhargava (2015) conducted an experiment in Karnataka on honey bee visitation in sunflower crop. Results reported that the plot which received the bee attractants significantly enhanced the seed set, seed weight and germination of sunflower as compared to control plots. Osman and Nagi (2015) carried out research at NRC, Sudan and reported that highest seed set ratios of 80 and 79 per cent were obtained in the open (O) and honey bee (H) pollinated system. While only 45.2% seed setting was observed in the control (C) where plants were kept in closed system and away from insect pollination in sunflower crop.

2.2 Seasonal activities of *Apis mellifera* L. and *Trigona* sp.

At University of agricultural science, Banglore, Reddy *et al.* (1993) observed considerable seasonal fluctuation among different three species of honey bees viz., *Apis cerena indica*, *A. dorsata* and *A. florea*. The bees were active throughout the whole day from 07.00 to 18.00 hrs on sunflower crops. The peak activity of bees was observed at 09:00 hrs.

Yucel and Duman (2005) studied effect of foraging activity of honey bees *(A. mellifera* L.) on onion (*Allium cepa*) seed production and quality in turkey and reported that *A. mellifera* foraged on onion plant from 8:15 hrs to 16:30 hrs with peak foraging between 11:00 hrs to 12:00 hrs. At 09:00 hrs, 12:00 hrs and 15:00 hrs average bees visits were 8, 13 and 4 flowers per minute.

Asif *et al.* (2008) studied role of different pollinators on pollination of onion in Pakistan and reported that among bees, *A. dorsata* proved to be an abundant pollinator (2.85 ± 1.57 individuals/25 plants). Mupade *et al*. (2009) studied relative abundance of different insect poliinators on onion in Maharashtra and reported that honey bees started visiting the crop at 8.00 hrs, high activity were found during 13.00-16.00 hrs and declined slowly during 16.00-18.00 hrs.

Sreedevi and Jadhav (2010) studied pollinator diversity, foraging ecology and role of honey bees in seed production of sunflower (*Helianthus annus* L.) at Tirupati and reported that among different honey bees, *A. dorsata* and *A. mellifera* were the dominant species on hybrid and parental lines, respectively. The foraging activity of major pollinators was high during 10.00 hrs and 11.00 hrs.

Studies were conducted by Ali *et al*. (2015) in Pakistan and reported that the peak activities of honey bee species were recorded at 12:00 pm and 02:00 pm while minimum activities were recorded at 08:00 am and 04:00 pm.

3. MATERIALS AND METHODS

The study on role of honey bees on seed production and other related attributes were carried out at Department of Entomology, B. A. College of Agriculture, Anand Agricultural University, Anand (Gujarat). Meteorological data were also recorded as per the format of research. Studies on foraging and seasonal activities of honey bees were carried out for sunflower at Agronomy farm, Anand Agricultural University, Anand during *Kharif*, 2017 and *rabi,* 2017-18 and for onion at Main Vegetable Research Station, AAU, Anand during *rabi*, 2017 and *rabi*, 2018.

3.1 Effect of honey bee pollination on yield and other related attributes

3.1.1 Methodology to study the effects of honey bee pollination on yield and other related attributes in seed production of sunflower

For these studies, sunflower crop was sown during *kharif*, 2017 and *rabi,* 2017-18. All the recommended agronomical practices were followed to raise the crop. The plot was kept free from insecticidal spray. The experiment was conducted in Randomized Block Design with six treatments and four replications.

Fine nylon mosquito nets of 6 x 6 feet (mesh 20 micron) size were erected over the sunflower crop for the treatment T_2, T_3 and T_4. Inside the nets of T_3 treatment, one framed box of *A. mellifera* L. and for T_4 treatment, a colony of *Trigona* sp. was kept and T_2 as such under mosquito net covered while remaining T_1, T_5 and T_6 treatments were kept open at five per cent flowering to determine the foraging activity of honey bees and its effect on crop yield (Plate I).

Five per cent sugar and jaggery solutions were applied on crops kept in open in the morning time at five per cent flowering and subsequent two sprays were given at an interval of 10 days.

The bee visit was recorded as number of honey bees visiting five capitula per two minutes at three time intervals viz., 08:00 to 10:00, 10:00 to 12:00 and 14:00 to 16:00 hrs. Observations were recorded before spray as well as 1, 3, 5 and 7 days after spray.

Randomly selected five capitula were sampled from all replications to record improvement in qualitative as well as quantitative parameters of seeds due to foraging activity of honey bees. The capitula were sampled when the seeds became black and ready to harvest. Evaluation on role of honey bees for the production of sunflower seeds as well as different seed quality parameters like yield, head diameter, head weight per plant,

number of filled seeds per head, weight of thousand seeds and seeds weight per head, seed number, percent wrinkled seeds and oil per cent were recorded and different quality parameters like germination percentage and per cent seed setting were also recorded after harvesting the crop.

Details of Experiment :

Location	Agronomy farm, Anand Agricultural University, Anand
Design of the experiment	Randomized Block Design
Treatments	1. Open pollination (OP) 2. Pollination without Insect (PWI) covered with net 3. One framed *A. mellifera* colony covered with net 4. *Trigona* sp. colony covered with net 5. Sugar solution spray (5%) in open plot 6. Jaggery solution spray (5%) in open plot
Replications	Four
Crop and variety	Sunflower, NSH-10
Season and year	*Kharif*, 2017 and *rabi*, 2017-18
Plot size	Gross : 2.00 × 1.80 m Net : 1.80 × 0.90 m
Spacing	45 × 10 cm
Fertilizer dose (N:P:K)	90:45:00 (kg / ha)

3.1.2 Record of Experimental Observations

For recording of observations, randomly selected five capitula of sunflower were sampled from all replications to note down improvement in qualitative as well as quantitative parameters of seeds due to foraging activity of honey bees.

3.1.2.1 Head diameter (cm)

The diameter of the heads from five randomly selected plants in each replication were measured. The average diameter was worked out and expressed in centimeters.

3.1.2.2 Number of filled seeds per head

The seeds obtained from each head of five sample plants from each replication were cleaned separately. The total number of seeds were manually separated, counted, totaled and average was worked out.

3.1.2.3 Weight 1000 seed weight (g)

Thousand seeds were counted manually from the treatments. The weight of thousand seeds was recorded in grams.

3.1.2.4 Wrinkled seeds (%)

Five heads from each treatment were harvested. After thorough cleaning, the seeds were kept for drying up to proper seed moisture and then wrinkled seeds were calculated out of 100 seeds.

3.1.2.5 Germination (%)

It was carried out under laboratory conditions by germinating of randomly selected 100 seeds from each treatments.

3.1.2.6 Seed setting (%)

Seed setting percentage were calculated by using following formula:

Seed set (%) = 100 X Number of filled seeds / Total number of seeds per capitulum

3.1.2.7 Oil percentage

Randomly selected seed samples from different treatments were brought to the Department of Bio-chemistry, B. A. college of Agriculture, Anand Agricultural University, Anand and oil content from the sunflower seeds were calculated by using Soxhlet extraction method a standard procedure.

3.1.2.8 Yield (kg/ ha)

Yield were recorded after harvesting of the crop (kg/ ha).

3.1.3 Methodology to study the effects of honey bee pollination on yield and other related attributes in seed production of onion

Onion was sown in field during *rabi*, 2017 and 2018 and all the recommended agronomical practices were followed to raise the crop. The plot was kept free from insecticidal spray. Experiment was conducted in Randomized Block Design with six treatments and four replications which was divided equally into equal quadrates to take observations of bees visit.

Fine nylon mosquito nets of 6 x 6 feet (mesh 20 micron) size were erected over the sunflower crop for the treatment T_2, T_3 and T_4. Inside the nets of T_3 treatment, one framed box of *A. mellifera* L. and for T_4 treatment, a colony of *Trigona* sp. was kept and T_2 as such under mosquito net covered while remaining T_1, T_5 and T_6 treatments were kept open at five per cent flowering to determine the foraging activity of honey bees and its effect on crop yield (Plate II).

Five per cent sugar and jaggery solutions were applied on crops kept in open in the morning time at flowering and subsequent two sprays were given at an interval of 10 days.

One square meter area was randomly selected and honey bees visiting onion umbels per two min was recorded throughout the day from 08:00 to 10:00, 10:00 to 12:00 and 14:00 to 16:00 hrs. Observations of bee visit were recorded before spray as well as 1, 3, 5 and 7 days after every spray.

To evaluate the role of honey bees pollination on the production of onion seeds, different seed quality parameters like total seed yield/plot, umbel weight, weight of thousand seeds, seed number, percent wrinkled seeds and germination % age were recorded as per described in section 3.1.2.

Details of Experiment :

Location	Main Vegetables Research Station, Anand Agricultural University, Anand.
Design of the experiment	Randomized Complete Block Design
Treatments	1. Open pollination (OP) 2. Net covered plants 3. One framed *A. mellifera* colony covered with net 4. *Trigona* sp. colony covered with net 5. Sugar solution spray (5%) in open plot 6. Jaggery solution spray (5%) in open plot
Replications	Four
Crop and variety	Onion, GAWO – 2
Season and year	*Rabi*, 2017 & 2018
Plot size	Gross : 1.80 × 1.80 m Net : 1.50 × 0.90 m
Spacing	45 × 15 cm
Fertilizer dose (N:P:K)	100:50:50 (kg/ha)

3.2 Seasonal activities of *Apis mellifera* L. and *Trigona* sp.

Seasonal activities of honey bees were noted on sunflower and onion by raising of crop without any application of attractants. One square meter area was randomly selected from both the plots during their crop periods. Observations were recorded during the first two min of every two hours from 08:00 to 10:00, 10:00 to 12:00, 12:00 to 14:00, 14:00 to 16:00 and 16:00 to 18:00 hrs by using a stopwatch. Observations were taken at weekly interval throughout flowering season.

Weekly meteorological data like maximum and minimum temperature, morning and evening relative humidity, wind speed, bright sunshine hours and rainfall were obtained from Agricultural Meteorological Observatory, AAU, Anand which were correlated with foraging data.

3.2.3 Statistical analysis:

Experimental data were analyzed as per ANOVA technique (Steel and Torrie, 1980) after suitable transformation.

4. RESULTS AND DISCUSSION

The investigations on utilization of honey bees (*Apis mellifera* L. and *Trigona* sp. covered under mosquito net conditions were conducted with broad aspects like flowers visited by honey bees, effect of pollination by honey bees on various qualitative and quantitative characters of sunflower and onion crops. These experiments were carried out at Anand Agricultural University, Anand during 2017 and 2018. The results obtained are presented here in this chapter. The results are also discussed in relation to the research work done elsewhere which are directly or indirectly related with the present investigations.

4.1 Effects of honey bee pollination on various qualitative and quantitative characters of sunflower crops

4.1.1 Recording of bee visit

Investigations were carried out on effects of bees visitation for sunflower during *kharif*, 2017 and *rabi*, 2017-18 at Anand Agricultural University, Anand.

The observations were recorded on the bees visitation in relation to pollination from randomly selected head/ capitula of sunflower crops.

The bee visits were recorded as number of honey bees visited on 5 capitula per 2 minutes at three time intervals *viz.*, 08:00 to 10:00, 10:00 to 12:00 and 14:00 to 16:00 hrs of sunflower crop. Observations of bee visits were recorded before spray as well as 1, 3, 5 and 7 days after sprays. Subsequent two sprays were given at an interval of ten days. The observations were started from 5% flowering of sunflower crop and data were statistically analyzed.

4.1.1.1 Bee visitation during *kharif*, 2017

First spray:

Observations were recorded on *A. mellifera* and *Trigona* sp. visitation on sunflower capitulum from five per cent flowering periods during *kharif*, 2017 (Table 4.1).

The observations recorded one day before the first spray indicated that number of bees visited to sunflower ranged from 0.00 to 2.32 bees/ 5 capitula/ 2 minutes which differed significantly among all the treatments. Patil *et al.* (2010) also reported that a day before the first spray, the number of bees visited the flower ranged from 1.66 to 2.50 bees/ 5 capitula/ 2 minutes and did not differ significantly among the treatments.

Following a day after the first spray, maximum number of honey bees visited in the treatment of sugar solution five per cent spray (3.19 bees/ 5 capitula/ 2 minutes) in open plot and it was at par with treatment of jaggery solution five per cent spray (3.00) and a colony *Trigona* sp. covered with net (2.46), one framed *A. mellifera* colony covered with net (2.74). Minimum bee visits were recorded in the treatment of open pollination (2.22).

On third day after the first spray, maximum number of honey bees visited in the treatment of sugar solution five per cent spray in open plot (3.74) and it was at par with treatment of jaggery solution five per cent spray in open plot (3.46), one framed *A. mellifera* colony covered with net (3.22) and treatment of a colony *Trigona* sp. covered with net (3.00). Minimum bee visits were recorded in the treatment of open pollination (1.84).

Five days after the first spray, maximum number of honey bees visited in the treatment of sugar solution five per cent spray in open plot (2.96) and it was at par with treatment of jaggery solution five per cent spray in open plot (2.81), a colony *Trigona* sp. covered with net (2.74) and treatment of one framed *A. mellifera* colony covered with net (2.46). While, in the treatment of open pollination minimum visits of honey bees were found among all the treatments (1.52). In the treatment of pollination without insects, no any honey bee visits were recorded during investigations due to net covering.

After seven days of first spray, there were no any bee visit found outside or inside net conditions due to rainy days (Plate III).

The present results corroborate with the findings of Pateel and Sattagi (2007), who reported that treatment of sugar and jaggery solution attracted more honey

bees up to third day of first and second sprays, whereas their activities decreased at fifth day of sprays.

Table 4.1: Bee visits after first spray on sunflower head during *kharif*, 2017

Sr. No.	Treatments	No. of bees/ 5 capitula/ 2 minutes*			
		Before spray	**1**	**3**	**5**
T_1	Open pollination (OP)	1.54 (1.87)	1.65 (2.22)	1.53 (1.84)	1.42 (1.52)
T_2	Pollination without Insect (PWI) covered with net	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_3	One framed *A. mellifera* colony covered with net	1.64 (2.19)	1.80 (2.74)	1.93 (3.22)	1.72 (2.46)
T_4	*Trigona* sp. colony covered with net	1.65 (2.22)	1.72 (2.46)	1.87 (3.00)	1.80 (2.74)
T_5	Sugar solution spray (5%) in open plot	1.68 (2.32)	1.92 (3.19)	2.06 (3.74)	1.86 (2.96)
T_6	Jaggery solution spray (5%) in open plot	1.57 (1.96)	1.87 (3.00)	1.99 (3.46)	1.82 (2.81)
S. Em. ±		0.08	0.09	0.07	0.08
C.D. at 5%		0.23	0.29	0.22	0.24
C.V. %		10.22	11.41	8.06	9.77

Note: Figures in parentheses are retransformed values and those outside are $\sqrt{x + 0.5}$ transformed values*

*DAS= Days after spray

4.1.1.2 Bee visitation during *kharif*, 2017

Second spray

Observations were recorded on honey bees visitation on sunflower head during *kharif*, 2017 (Table 4.2).

The observations recorded one day before the first spray indicated that number of bees visited to sunflower ranged from 0.00 to 3.46 bees/ 5 capitula/ 2 minutes and differences were found of bee visited among all the treatments.

One day after the second spray, maximum number of honey bees visited in the treatment of sugar solution five per cent spray in open plot (3.70 bees/ 5 capitula/ 2 minutes) and it was at par with treatment of jaggery solution five per cent spray in open plot (3.46), one framed *A. mellifera* colony covered with net (3.29), a colony *Trigona* sp. covered with net (3.00) and open pollination (2.96).

On third day after the second spray, maximum number of honey bees visited in the treatment of sugar solution five per cent spray in open plot (3.00) and one framed *A. mellifera* colony covered with net (3.00). It was found at par with treatment of jaggery solution five per cent spray in open plot (2.74), open pollination (2.46) and a colony *Trigona* sp. covered with net (2.32).

Five days after the second spray, maximum number of honey bees visited in the treatment of jaggery solution five per cent spray in open plot (2.49) and it was at par with treatment of a colony *Trigona* sp. covered with net (2.46), one framed *A. mellifera* colony covered with net (2.46), sugar solution five per cent spray in open plot (2.36) and open pollination (2.22).

Maximum number of honey bees visited in the treatment of one framed *A. mellifera* colony covered with net (2.32) on seven days after the second spray and it was at par with treatment of sugar solution five per cent spray in open plot (2.26). Moreover, Treatments of jaggery solution five per cent spray in open plot (1.81), treatment of a colony *Trigona* sp. covered with net (1.81) and open pollination (1.52) were found at par with each other.

Pateel and Sattagi (2007) reported that treatment of sugar and jaggery solution attracted more honey bees up to third day of first and second sprays, whereas their

activities decreased at fifth day of sprays. These results are in accordance with the present findings.

4.1.1.3 Pooled over sprays during *kharif*, 2017

Results of pooled over sprays revealed that maximum bee activities were recorded on first and three days of both the sprays in all the treatments (Table 4.3). Following a day after first spray, maximum number of honey bees visited in the treatment of jaggery solution five per cent spray in open plot (3.22 bees/ 5 capitula/ 2 minutes) and it was at par with treatment of sugar solution five per cent spray in open plot (3.07), one framed *A. mellifera* colony covered with net (3.03), open pollination (2.96) and a *Trigona* sp. colony covered with net (2.70).

Three days after sprays, maximum number of honey bees visited in the treatment of jaggery solution five per cent spray in open plot (3.34) and it was at par with treatment of sugar solution five per cent spray in open plot (3.19), one framed *A. mellifera* colony covered with net (3.10) and open pollination (3.00). Treatment of a colony *Trigona* sp. covered with net (2.89) showed minimum bee visits as compared to other treatments.

Maximum number of honey bees visited in the treatment of sugar solution five per cent spray in open plot (3.08) in five days after sprays and it was at par with treatment of a colony *Trigona* sp. covered with net (2.86), one framed *A. mellifera* colony covered with net (2.60) and open pollination (2.60). In the treatment of jaggery solution five per cent spray in open plot (2.46) noted minimum bee visits.

After seven days of sprays, maximum number of honey bee visited in the treatment of jaggery solution five per cent spray in open plot (1.93) and it was at par with treatment of sugar solution five per cent spray in open plot (1.52). However, the treatment of sugar solution five per cent spray in open plot also found at par with one framed *A. mellifera* colony covered with net (1.43), treatment of a colony *Trigona* sp. covered with net (1.32) and open pollination (1.27).

Here, pooled data of bee visits found maximum in the treatments of sugar and jaggery five per cent spray as earlier said report of Patil *et al.* (2010).

4.1.1.4 Bee visitation during *rabi,* 2017-18

First spray

Observations were recorded on *A. mellifera* L. and *Trigona* sp. visitation on sunflower capitulum at five per cent flowering periods during *rabi,* 2017-18 (Table 4.4).

The observations recorded one day before the first spray indicated that number of bees visited to sunflower ranged from 0.00 to 3.46 bees/ 5 capitula/ 2 minutes and differed significantly among the treatments.

Following a day after the first spray, maximum number of honey bees visited in the treatment of sugar solution five per cent spray in open plot (4.47 bees/ 5 capitula/ 2 minutes) and it was at par with treatment of jaggery solution five per cent spray in open plot (4.21) and one framed *A. mellifera* colony covered with net (3.95). The next good treatment was a colony *Trigona* sp. covered with net (2.96) and it was found at par with treatment of open pollination (2.70).

After three days of first spray, maximum number of honey bees visited in the treatment of one framed *A. mellifera* colony covered with net (4.98) and sugar solution five per cent spray in open plot (4.21). The next good treatment was jaggery solution five per cent spray in open plot (3.95) and it was at par with treatment of a colony *Trigona* sp. covered with net (3.70) and open pollination (3.70).

There was no any visitation of honey bees noted on five and seven days after first spray treatments due to adverse climatic conditions in outside and inside of nets treatments (Plate IV).

The present results fall in same line with the findings of Pateel and Sattagi (2007), who reported that treatment of sugar and jaggery solution attracted more honey bees up to three days of first and second sprays, whereas their activities decreased after five days of sprays.

Table 4.2: Bee visits after second spray on sunflower head during *kharif*, 2017

Sr. No.	Treatments	No. of bees/ 5 capitula/ 2 minutes*				
		Before spray	**1**	**3**	**5**	**7**
T_1	Open pollination (OP)	1.79 (2.70)	1.86 (2.96)	1.72 (2.46)	1.65 (2.22)	1.42 (1.52)
T_2	Pollination without Insect (PWI) covered with net	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_3	One framed *A. mellifera* colony covered with net	1.78 (2.67)	1.92 (3.29)	1.87 (3.00)	1.72 (2.46)	1.68 (2.32)
T_4	*Trigona* sp. colony covered with net	1.79 (2.70)	1.87 (3.00)	1.78 (2.67)	1.72 (2.46)	1.52 (1.81)
T_5	Sugar solution spray (5%) in open plot	1.99 (3.46)	2.05 (3.70)	1.87 (3.00)	1.69 (2.36)	1.66 (2.26)
T_6	Jaggery solution spray (5%) in open plot	1.93 (3.22)	1.99 (3.46)	1.79 (2.70)	1.73 (2.49)	1.52 (1.81)
S. Em. ±		0.10	0.10	0.09	0.08	0.09
C.D. at 5%		0.30	0.29	0.27	0.24	0.28
C.V. %		11.60	10.63	10.78	9.89	11.61

Note: Figures in parentheses are retransformed values and those outside are $\sqrt{x + 0.5}$ transformed values

*DAS= Days after spray

Table 4.3: Bee visits in sunflower during *kharif*, 2017*

Sr. No.	Treatments	No. of bees/ 5 capitula/ 2 minutes**			
		1	3	5	7
T_1	Open pollination (OP)	1.86 (2.96)	1.87 (3.00)	1.76 (2.60)	1.33 (1.27)
T_2	Pollination without Insect (PWI) covered with net	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_3	One framed *A. mellifera* colony covered with net	1.88 (3.03)	1.94 (3.10)	1.75 (2.56)	1.39 (1.43)
T_4	*Trigona* sp. colony covered with net	1.79 (2.70)	1.84 (2.89)	1.83 (2.84)	1.35 (1.32)
T_5	Sugar solution spray (5%) in open plot	1.89 (3.07)	1.92 (3.19)	1.89 (3.07)	1.42 (1.52)
T_6	Jaggery solution spray (5%) in open plot	1.93 (3.22)	1.96 (3.34)	1.71 (2.42)	1.56 (1.93)
S. Em. ±		0.06	0.06	0.05	0.04
C.D. at 5%		0.19	0.17	0.16	0.13
C.V. %		10.61	9.61	10.05	9.79

Note: Figures in parentheses are retransformed values and those outside are $\sqrt{x + 0.5}$ transformed values

*Mean of two sprays

**DAS= Days after spray

Table 4.4: Bee visits after first spray on sunflower head during *rabi*, 2017-18

Sr. No.	Treatments	No. of bees/ 5 capitula/ 2 minutes*		
		Before spray	1	3
T_1	Open pollination (OP)	1.72 (2.46)	1.79 (2.70)	2.05 (3.70)
T_2	Pollination without Insect (PWI) covered with net	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_3	One framed *A. mellifera* colony covered with net	1.99 (3.46)	2.11 (3.95)	2.34 (4.98)
T_4	*Trigona* sp. colony covered with net	1.72 (2.46)	1.86 (2.96)	2.05 (3.70)
T_5	Sugar solution spray (5%) in open plot	1.86 (2.96)	2.23 (4.47)	2.17 (4.21)
T_6	Jaggery solution spray (5%) in open plot	1.52 (1.81)	2.17 (4.21)	2.11 (3.95)
S. Em. ±		0.09	0.07	0.09
C.D. at 5%		0.27	0.21	0.28
C.V. %		10.71	7.34	9.49

Note: Figures in parentheses are retransformed values and those outside are $\sqrt{x + 0.5}$ transformed values

*DAS= Days after spray

4.1.1.5 Bee visitation during *rabi,* 2017-18

Second spray

Observations were recorded on *A. mellifera* L. and *Trigona* sp. visitation on sunflower capitulum during *rabi*, 2017-18 (Table 4.5).

The observations recorded one day before the first spray indicated that number of bees visited to sunflower from 0.00 to 3.42 bees/ 5 capitula/ 2 minutes and differed significantly among the treatments.

Following a day after the second spray maximum number of honey bees visited in the treatment of jaggery solution five per cent spray in open plot (4.47 bees/ 5 capitula/ 2 minutes) and it was at par with treatment of sugar solution five per cent spray in open plot (3.78). The next best treatments were one framed *A. mellifera* colony covered with net (3.46) and a colony *Trigona* sp. covered with net (3.46). Minimum bee visits were noted in the treatment of open pollination (2.96).

After three days of second spray, maximum number of honey bees visited in the treatment of sugar solution five per cent spray in open plot (3.70). The next best treatment was jaggery solution five per cent spray in open plot (3.19) which was found at par with one framed *A. mellifera* colony covered with net (2.96), open pollination (2.92) and a colony *Trigona* sp. covered with net (2.671).

Maximum number of honey bees visited in the treatment of sugar solution five per cent spray in open plot (3.70) in five days after the second spray. The next best treatment was jaggery solution five per cent spray in open plot (3.19). However, one framed *A. mellifera* colony covered with net (2.70), open pollination (2.70) and treatment of a colony *Trigona* sp. covered with net (2.19) were found at par with each other.

After seven days of the second spray, maximum number of honey bees visited in the treatment of sugar solution five per cent spray in open plot (2.70) and it was at par with treatment of one framed *A. mellifera* colony covered with net (2.67). The next good treatment was treatment of *Trigona* sp. colony covered with net (2.22). Minimum bee visits were recorded in jaggery solution five per cent spray in open plot (2.19) and open pollination (1.84).

In nutshell, maximum number of bee visits were found in the treatments of sugar and jaggery five per cent spray solutions in open plots due to the strong olfactory sensory of bees. So, bees attract more towards those capitula on which sugar and jaggery solutions were sprayed. These present results coincide with the findings of Pateel and Sattagi (2007), who reported that treatment of sugar and jaggery solutions attracted more honey bees up to three days of first and second sprays, whereas their activities decreased at five days of sprays.

Table 4.5: Bee visits after second spray on sunflower head during *rabi*, 2017-18

Sr. No.	Treatments	No. of bees/ 5 capitula/ 2 minutes*				
		Before spray	1	3	5	7
T_1	Open pollination (OP)	1.72 (2.46)	1.86 (2.96)	1.85 (2.92)	1.79 (2.70)	1.53 (1.84)
T_2	Pollination without Insect (PWI) covered with net	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_3	One framed *A. mellifera* colony covered with net	1.98 (3.42)	1.99 (3.46)	1.86 (2.96)	1.79 (2.70)	1.78 (2.67)
T_4	*Trigona* sp. colony covered with net	1.86 (2.96)	1.99 (3.46)	1.78 (2.67)	1.64 (2.19)	1.65 (2.22)
T_5	Sugar solution spray (5%) in open plot	1.86 (2.96)	2.07 (3.78)	2.05 (3.70)	1.86 (2.96)	1.79 (2.70)
T_6	Jaggery solution spray (5%) in open plot	1.79 (2.70)	2.23 (4.47)	1.92 (3.19)	1.86 (2.96)	1.64 (2.19)
S. Em. ±		0.08	0.10	0.10	0.08	0.08
C.D. at 5%		0.23	0.31	0.29	0.25	0.24
C.V. %		8.99	11.31	11.48	10.15	9.90

Note: Figures in parentheses are retransformed values and those outside are $\sqrt{x + 0.5}$ transformed values

*DAS= Days after spray

4.1.1.6 Pooled over sprays during *rabi,* 2017-18

The data on pooled over sprays of two sprays given during *rabi,* 2017-18 indicated that one day after sprays were recorded maximum number of bee visit 3.95 bees/ 5 capitula/ 2 minutes in all the different periods from 1, 3, 5 and 7 days after spray. Furthermore, visit of bees showed declined with number of days increased of subsequent sprays (Table 4.6).

Maximum number of honey bee visits were found in the treatment of one framed *A. mellifera* colony covered with net (3.95 bees/ 5 capitula/ 2 minutes) in a day after sprays and it was at par with sugar spray 5% (3.83), jaggery solution spray 5% (3.78) and open pollination (3.46) while, treatment of a colony *Trigona* sp. covered with net (3.19) showed minimum bee visits.

After three days of both the sprays, maximum number of honey bee visited in the treatment of sugar solution spray 5% (3.66). The next effective treatment was one framed *A. mellifera* colony covered with net (3.78). Moreover, in the treatment of jaggery solution five per cent spray recorded minimum bee visits (3.30) followed by a colony *Trigona* sp. covered with net (2.96) and open pollination (2.96).

Five days after sprays, maximum number of honey bee visited in the treatment of jaggery spray 5% (2.96). One framed *A. mellifera* colony covered with net (1.54), sugar solution spray 5% (1.54) and open pollination (1.43) were significantly at par with each other in respect to honey bee activities. Treatment of a *Trigona* sp. colony covered with net (1.24) were showed minimum of bee visits.

After seven days of sprays, maximum number of honey bee visited in the treatment of one framed *A. mellifera* colony covered with net (1.43) and jaggery solution spray 5% (1.43), which was found at par with sugar solution spray 5% (1.35). The next effective treatment was a colony of *Trigona* sp. covered with net (1.14) while, open pollination showed minimum bee visits (1.04). The results of present investigations were found similar with the findings of Pateel and Sattagi (2007), treatments of sugar and jaggery solution attracted more bees up to third day of sprays whereas their efficacy decreased at five days of sprays.

Table 4.6: Bee visits in sunflower during *rabi*, 2017-18*

Sr. No.	Treatment	No. of bees/ 5 capitula/ 2 minutes**			
		1	3	5	7
T_1	Open pollination (OP)	1.99 (3.46)	1.86 (2.96)	1.39 (1.43)	1.24 (1.04)
T_2	Pollination without Insect (PWI) covered with net	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_3	One framed *A. mellifera* colony covered with net	2.11 (3.95)	2.07 (3.78)	1.43 (1.54)	1.39 (1.43)
T_4	*Trigona* sp. colony covered with net	1.92 (3.19)	1.86 (2.96)	1.32 (1.24)	1.28 (1.14)
T_5	Sugar solution spray (5%) in open plot	2.08 (3.83)	2.04 (3.66)	1.43 (1.54)	1.36 (1.35)
T_6	Jaggery solution spray (5%) in open plot	2.07 (3.78)	1.95 (3.30)	1.86 (2.96)	1.39 (1.43)
S. Em. ±		0.06	0.07	0.04	0.03
C.D. at 5%		0.18	0.19	0.13	0.11
C.V. %		9.56	10.21	9.36	4.86

Note: Figures in the parentheses are retransformed values and those outside are $\sqrt{x+0.5}$ transformed values

*Mean of two sprays

** DAS= Days after spray

4.1.2 Effect of bees pollination on various qualitative and quantitative characters

The results of the experiment conducted during *kharif*, 2017 and *rabi*, 2017-18 are presented here below:

4.1.2.1 Effect of bees pollination on various quantitative and quantitative characters

The data on various quantitative characters of sunflower crop during *kharif*, 2017 (Table 4.7) indicated that the treatment of jaggery solution five per cent was found significantly superior by showing head diameter (36.25 cm), head weight (1670 gm), number of filled seeds per head (1975), weight of thousand seeds (65 gm), seed weight per head (640 gm), total number of seeds/ head (1985) and yield (1530 kg/ ha). Treatment of sugar solution five per cent was found next effective treatment by showing head diameter (34.75 cm), head weight (1650 gm), number of filled seeds per head (1930), weight of thousand seeds (60 gm), seed weight per head (610 gm), total number of seeds/ head (1980) and yield (1520 kg/ ha). However, it was at par with the treatment of one framed *A. mellifera* colony covered with net which showed head diameter (33.75 cm), head weight (1660 gm), number of filled seeds per head (1860), weight of thousand seeds (55 gm), seed weight per head (585 gm), total number of seeds/ head (1840) and yield (1525 kg/ ha). Treatments of open pollination and pollination without insects were found less effective and showed lower head diameter (26.25 and 17.50 cm), head weight (1550 and 1520 gm), number of filled seeds per head (1810 and 1640), weight of thousand seeds (42 and 38 gm), seed weight per head (480 and 380 gm), total number of seeds/ head (1880 and 1675) and yield (1380 and 1255 kg/ ha), respectively. The results revealed that the treatments of Italian bees were found significantly superior among all the treatments. It might be due to more number of bee visitation recorded in these treatments.

The data (Table 4.8) on various qualitative characters of sunflower crop during *kharif*, 2017 showed that the treatment of jaggery solution five per cent was found significantly superior by recording wrinkled seeds (13%) and oil (42%) but more germination (91%) and seed setting (92%) were found in the treatment of sugar solution five per cent as noted germination (95%) and seed setting (96%). Treatment of sugar solution five per cent was found next effective treatment by recording wrinkled seeds

(10%) and oil per cent (40%) which also found at par with the treatment of one framed *A. mellifera* colony covered with net by recording wrinkled seeds (12%), oil per cent (38%), germination (97%) and seed setting (97%) (Plate V). Treatments of open pollination and pollination without insects were found less effective and showed wrinkled seeds (24 and 36%), oil per cent (30 and 28%), germination (89 and 79%) (Plate VI) and seed setting (81 and 65%), respectively. The results revealed that the treatments of sugar and jaggery solution five per cent sprays were found significantly superior among all the treatments. It might be due to more number of bee visitations in these treatments resulting in production of bold seeds reflected in seed qualities.

The data on various quantitative characters of sunflower crop during *rabi,* 2017-18 indicated that the treatment of jaggery solution five per cent was found significantly superior by showing head diameter (39.75 cm), head weight (1720 gm), number of filled seeds per head (1965), weight of thousand seeds (68 gm), seed weight per head (625 gm), total number of seeds/ head (1990) and yield (1610 kg/ ha). Treatment of sugar solution five per cent was found next effective treatment by indicating head diameter (38.25 cm), head weight (1680 gm), number of filled seeds per head (1950), weight of thousand seeds (62 gm), seed weight per head (630 gm), total number of seeds/ head (1995) and yield (1640 kg/ ha). However, it was at par with the treatment of one framed *A. mellifera* colony covered with net which showed head diameter (34.50 cm), head weight (1710 gm), number of filled seeds per head (2000), weight of thousand seeds (57 gm), seed weight per head (590 gm), total number of seeds/ head (1890) and yield (1635 kg/ ha). Treatments of open pollination and pollination without insects were found less effective and showed lower head diameter (26.75 and 16.50 cm), head weight (1560 and 1480 gm), number of filled seeds per head (1825 and 1680), weight of thousand seeds (45 and 35 gm), seed weight per head (495 and 425 gm), total number of seeds/ head (1840 and 1695) and yield (1360 and 1345 kg/ ha), respectively. The results revealed that the treatment in which Italian bees were used found significantly superior among all the treatments. It might be due to more number of bee visitation recorded in these treatments (Table 4.9).

The data on various qualitative characters of sunflower crop during *rabi,* 2017-18 showed that the treatment of jaggery solution five per cent was found significantly superior by recording wrinkled seeds (11%) and oil per cent (41.5%) while

more germination (90%) and seed setting (91%) were found in the treatment of sugar solution five per cent as recorded germination (92%) and seed setting (94%). Treatment of sugar solution five per cent was found next effective treatment recording wrinkled seeds (12.5%) and oil per cent (43%) also found at par with the treatment of one framed *A. mellifera* colony covered with net by recording wrinkled seeds (13.5%), oil per cent (35%), germination (88%) and seed setting (85%). Treatments of open pollination and pollination without insects were found less effective and showed wrinkled seeds (26.5 and 42%), oil per cent (32 and 30%), germination (88 and 75%) and seed setting (85 and 68%), respectively. The results revealed that the treatments of sugar and jaggery solution five per cent sprays were found significantly superior among all the treatments. It might be due to more number of bee visitations in these treatments (Table 4.10).

The results obtained in these studies indicated a significant increase in the percentage of seed setting, number of filled seeds per head, weight of thousand seeds, seed weight per head were noted higher in the plants on which sugar and jaggery like phagostimulants given due to best olfactory sensory found in honey bees. So, it may be responsible to attract more bees. This was due to the effect of honey bees pollination on the sunflower crop. These results are in agreement with the finding of Moreti *et al.* (1996) who have reported that the number and weight of seeds and percentage of seed setting were significantly higher in the plant visited by honey bees. Oz *et al.* (2009) also reported that pollination by honey bees in seed production of sunflower hybrid improved seed set ratio, hundred seed weight, number of filled seed per head and seed yield per head. Krishna *et al.* (2014) reported that the seeds/ capitulum (1278), thousand seeds weight (47.3 g) and per cent wrinkled seeds (8.2) were maximum in *A. mellifera* pollinated sunflower crop. Sireesha (2008) also reported the increased in head diameter of sunflower in five per cent sugar spray (14.80 cm).

In the present investigations, qualitative and quantitative parameters were lower in net covered plants without honey bees. The probable reason for this might be due to absence of bees population for transfer of pollen from one plant to another plant. Here, wind was only the medium for pollination in which is inadequate so qualitative and quantitative characters of seeds are not as obtained in honey bee pollinating sunflower crop.

Honey bees are found major pollinators of sunflower crops and addition to this, phagostimulant's solution lead towards more visits of bees on capitula of sunflower crop. In nutshell, pollination carried out by honey bee, *A. mellifera* with sprays of sugar and jaggery solutions resulted in not only higher yield of the sunflower crop but also increased qualitative and quantitative attributes.

Table 4.7: Effect of bees pollination on various quantitative characters of sunflower crop during *kharif*, 2017

Sr. No.	Treatments	Head diameter (cm)	Fresh head weight (g)	Number of filled seed per head	Weight of 1000 seed (g)	Seed weight per head (g)	Total number of seeds/ head	Yield (kg/ ha)
T_1	Open pollination (OP)	26.25	1550	1810	42	480	1880	1380
T_2	Pollination without Insect (PWI) covered with net	17.50	1520	1640	38	380	1675	1255
T_3	One framed *A. mellifera* colony covered with net	33.75	1660	1860	55	585	1840	1520
T_4	*Trigona* sp. colony covered with net	25.25	1550	1750	44	520	1760	1385
T_5	Sugar solution spray (5%) in open plot	34.75	1650	1930	60	610	1980	1525
T_6	Jaggery solution spray (5%) in open plot	36.25	1670	1975	65	640	1985	1530
S. Em. ±		2.16	30.00	91.82	2.52	20.12	91.82	76.45
C.D. at 5%		6.50	90.42	276.71	7.60	60.63	276.71	230.39
C.V. %		16.41	12.50	15.65	11.97	12.63	14.66	12.82

Table 4.8: Effect of bees pollination on various qualitative characters of sunflower crop during *kharif*, 2017

Sr. No.	Treatments	Wrinkled seeds (%)	Oil (%)	Germination (%)	Seed setting (%)
T_1	Open pollination (OP)	24	30	89	81
T_2	Pollination without Insect (PWI) covered with net	36	28	79	65
T_3	One framed *A. mellifera* colony covered with net	12	38	97	97
T_4	*Trigona* sp. colony covered with net	14.5	33	81	87
T_5	Sugar solution spray (5%) in open plot	10	40	95	96
T_6	Jaggery solution spray (5%) in open pot	13	42	91	92
S. Em. ±		3.75	1.75	2.46	4.41
C.D. at 5%		11.28	5.26	7.40	13.28
C.V. %		13.66	14.72	6.57	10.86

Table 4.9: Effect of bees pollination on various quantitative characters of sunflower crop during *rabi*, 2017-18

Sr. No.	Treatments	Head diameter (cm)	Fresh head weight (g)	Number of filled seed per head	Weight of 1000 seed (g)	Seed weight per head (g)	Total number of seeds/ head	Yield (kg/ ha)
T_1	Open pollination (OP)	26.75	1560	1825	45	495	1840	1360
T_2	Pollination without Insect (PWI) covered with net	16.50	1480	1680	35	425	1695	1345
T_3	One framed *A. mellifera* colony covered with net	34.50	1710	2000	57	590	1890	1635
T_4	*Trigona* sp. colony covered with net	28.00	1585	1820	42	505	1835	1295
T_5	Sugar solution spray (5%) in open plot	38.25	1680	1950	62	630	1995	1640
T_6	Jaggery solution spray (5%) in open plot	39.75	1720	1965	68	625	1990	1610
S. Em. ±		2.03	42.36	76.84	2.23	20.84	85.26	86.05
C.D. at 5%		6.12	127.65	231.57	6.73	62.81	256.95	259.32
C.V. %		14.92	14.93	13.00	10.12	12.58	14.34	21.64

Table 4.10: Effect of bees pollination on various qualitative characters of sunflower crop during *rabi*, 2017-18

Sr. No.	Treatments	Wrinkled seeds (%)	Oil (%)	Germination (%)	Seed setting (%)
T_1	Open pollination (OP)	26.5	32	88	85
T_2	Pollination without Insect (PWI) covered with net	42	30	75	68
T_3	One framed *A. mellifera* colony covered with net	13.5	35	96	98
T_4	*Trigona* sp. colony covered with net	13.0	31	80	89
T_5	Sugar solution spray (5%) in open plot	12.5	43	92	94
T_6	Jaggery solution spray (5%) in open plot	11	41.5	90	91
S. Em. ±		4.20	1.93	3.14	4.71
C.D. at 5%		12.66	5.80	9.47	14.21
C.V. %		15.15	15.82	8.15	11.47

Investigations were carried out on effects of bee visitations on onion during *rabi*, 2017 and 2018 at Main Vegetables Research Station, AAU, Anand. The bee visits were recorded on number of honey bees visited per umbel per 2 minutes in one square meter area at three time intervals *viz*., 08:00 to 10:00, 10:00 to 12:00 and 14:00 to 16:00 hrs. Observations of bee visits were recorded before spray as well as 1, 3, 5 and 7 days after sprays. Subsequent two sprays were given at an interval of ten days. The observations were recorded during flowering of onion crop and data were statistically analyzed.

4.1.3 Bee visits in onion crop

4.1.3.1 Bee visitation during *rabi,* 2017

First spray

Observations were recorded on *A. mellifera* L. and *Trigona* sp. visitation on onion umbels at flowering periods during *rabi,* 2017 (Table 4.11).

The observations recorded one day before first spray indicated that number of bees visited to onion umbels ranged from 0.00 to 2.96 bees/ m^2/ 2 minutes and differed significantly among the treatments.

Following a day after the first spray, maximum number of honey bees visited in the treatment of jaggery solution five per cent spray in open plot (3.46 bees/ m^2/ 2 minutes). The next best treatment was sugar solution five per cent spray in open plot (3.00) and one framed *A. mellifera* colony covered with net (2.96) and it was found at par with a colony of *Trigona* sp. covered with net (2.70). Here, treatment open pollination (2.46) found at par with a colony of *Trigona* sp. covered with net.

Three days after the first spray, maximum number of honey bees visited in the treatment of sugar solution five per cent spray in open plot (3.70) and it was at par with treatment of one framed *A. mellifera* colony covered with net (3.22) and jaggery solution spray 5% (2.96). The treatment of jaggery solution five per cent spray in open plot (2.96) was also found at par with a colony *Trigona* sp. covered with net (2.70) and open pollination (2.22).

After five days of first spray, maximum number of honey bees visited in the treatment of sugar solution five per cent spray in open plot (3.46) and it was at par with

treatment of one framed *A. mellifera* colony covered with net (2.96), jaggery solution five per cent spray in open plot (2.70) and a colony *Trigona* sp. covered with net (2.67).

On seven day after spray, maximum number of honey bees visited in the treatment of jaggery solution five per cent spray in open plot (1.65) and it was at par with treatment of sugar solution five per cent spray in open plot (1.64), a colony *Trigona* sp. covered with net (2.19), one framed *A. mellifera* colony covered with net (1.57) and open pollination (1.52).

It is clearly indicated from data that maximum number of bee visits were found in the treatments of sugar and jaggery five per cent spray solution. It might be due to attraction of honey bees toward sweet materials.

4.1.3.2 Bee visitation during *rabi,* 2017

Second spray

Observations were recorded on *A. mellifera* L. and *Trigona* sp. visitation on onion umbels during *rabi,* 2017 (Table 4.12).

The observations recorded one day before the first spray indicated that number of bees visited to onion umbels ranged from 0.00 to 2.70 bees/ m^2/ 2 minutes and differed significantly among the treatments.

One day after the second spray, maximum number of honey bees visited in the treatment of jaggery solution five per cent spray in open plot (3.74 bees/ m^2/ 2 minutes) and it was at par with treatment of sugar solution five per cent spray in open plot (3.70), one framed *A. mellifera* colony covered with net (3.46), open pollination (3.19) and a colony *Trigona* sp. covered with net (2.96).

Three days after second sprays, maximum number of honey bees visited in the treatments of jaggery solution five per cent spray in open plot (2.70) and one framed *A. mellifera* colony covered with net (2.70) and found at par with sugar solution five per cent spray in open plot (2.46), open pollination (2.22) and a colony *Trigona* sp. covered with net (2.19).

After five days of second spray, maximum number of honey bees visited in the treatment of sugar solution five per cent spray in open plot (2.29) and it was at par with treatment of jaggery solution five per cent spray in open plot (2.22), one framed *A.*

mellifera colony covered with net (2.19). Here, a colony *Trigona* sp. covered with net (1.96) and open pollination (1.84) showed minimum number of bee visits on sunflower head.

After seven days of second spray, maximum number of honey bees visited in the treatment of one framed *A. mellifera* colony covered with net (2.00), jaggery solution five per cent spray in open plot (1.96), sugar solution five per cent spray in open plot (1.96), a colony *Trigona* sp. covered with net (1.72) and open pollination (1.52).

Table 4.11: Bee visits after first spray on onion umbels during *rabi*, 2017

Sr. No.	Treatments	No. of bees/ m^2 / 2 minutes*				
		Before spray	1	3	5	7
T_1	Open pollination (OP)	1.64 (2.19)	1.72 (2.46)	1.65 (2.22)	1.57 (1.96)	1.42 (1.52)
T_2	Net covered plants	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_3	One framed *A. mellifera* colony covered with net	1.72 (2.46)	1.86 (2.96)	1.93 (3.22)	1.86 (2.96)	1.57 (1.96)
T_4	*Trigona* sp. colony covered with net	1.78 (2.67)	1.79 (2.70)	1.79 (2.70)	1.78 (2.67)	1.64 (2.19)
T_5	Sugar solution spray (5%) in open plot	1.86 (2.96)	1.87 (3.00)	2.05 (3.70)	1.99 (3.46)	1.64 (2.19)
T_6	Jaggery solution spray (5%) in open plot	1.79 (2.70)	1.99 (3.46)	1.86 (2.96)	1.79 (2.70)	1.65 (2.22)
S. Em. ±		0.09	0.07	0.07	0.10	0.09
C.D. at 5%		0.27	0.21	0.22	0.29	0.27
C.V. %		11.03	8.31	8.42	11.27	11.43

Note: Figures in the parentheses are retransformed values and those outside are $\sqrt{x + 0.5}$ transformed values

* DAS= Days after spray

Table 4.12: Bee visits after second spray on umbels of onion during *rabi*, 2017

Sr. No.	Treatments	No. of bees/ m^2 / 2 minutes*				
		Before spray	1	3	5	7
T_1	Open pollination (OP)	1.53 (1.84)	1.92 (3.19)	1.65 (2.22)	1.53 (1.84)	1.42 (1.52)
T_2	Net covered plants	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_3	One framed *A. mellifera* colony covered with net	1.72 (2.46)	1.99 (3.46)	1.79 (2.70)	1.64 (2.19)	1.58 (2.00)
T_4	*Trigona* sp. colony covered with net	1.57 (1.96)	1.86 (2.96)	1.64 (2.19)	1.57 (1.96)	1.49 (1.72)
T_5	Sugar solution spray (5%) in open plot	1.79 (2.70)	2.05 (3.70)	1.72 (2.46)	1.67 (2.29)	1.57 (1.96)
T_6	Jaggery solution spray (5%) in open plot	1.65 (2.22)	2.06 (3.74)	1.79 (2.70)	1.65 (2.22)	1.57 (1.96)
S. Em. ±		0.08	0.09	0.09	0.08	0.07
C.D. at 5%		0.23	0.25	0.27	0.23	0.21
C.V. %		10.07	9.55	11.50	10.28	9.90

Note: Figures in the parentheses are retransformed values and those outside are $\sqrt{x + 0.5}$ transformed values

* DAS= Days after spray

Table 4.13: Bee visits in onion during *rabi*, 2017*

Sr. No.	Treatment	No. of bees/ m^2 /2 minutes**			
		1	3	5	7
T_1	Open pollination (OP)	1.86 (2.96)	1.75 (2.56)	1.67 (2.29)	1.53 (1.84)
T_2	Net covered plants	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_3	One framed *A. mellifera* colony covered with net	1.96 (3.34)	1.86 (2.96)	1.71 (2.42)	1.72 (2.46)
T_4	*Trigona* sp. colony covered with net	1.83 (2.85)	1.72 (2.46)	1.67 (2.29)	1.56 (1.93)
T_5	Sugar solution spray (5%) in open plot	1.89 (3.07)	1.85 (2.92)	1.81 (2.78)	1.60 (2.06)
T_6	Jaggery solution spray (5%) in open plot	1.92 (3.19)	1.82 (2.81)	1.68 (2.32)	1.61 (2.09)
S. Em. ±		0.05	0.05	0.06	0.06
C.D. at 5%		0.15	0.17	0.18	0.16
C.V. %		8.67	9.98	11.43	10.76

Note: Figures in the parentheses are retransformed values and those outside are $\sqrt{x + 0.5}$ transformed values

*Mean of two sprays

** DAS= Days after spray

4.1.3.3 Pooled over sprays during *rabi,* 2017

The data on pooled over sprays of two sprays during *rabi,* 2017 indicated that following days after sprays showed maximum number of bee visit 3.34 bees/ m^2/ 2 minutes during different periods 1, 3, 5 and 7 days after sprays. Furthermore, visit of bees declined with number of days increased of sprays (Table 4.13).

One day after spray, data revealed that maximum number of bee visits were found in the treatment of one framed *A. mellifera* colony covered with net (3.34 bees/ m^2/ 2 minutes) and it was at par with jaggery solution spray 5% (3.19), sugar solution spray 5% (3.07). Minimum number of bee visits were recorded in the treatments of a colony *Trigona* sp. covered with net (2.85) and open pollination (2.96).

Three days after spray, maximum number of bees visited in the treatment of one framed *A. mellifera* colony covered with net (2.96) and it was at par with sugar solution spray 5% (2.92), jaggery solution spray 5% (2.81). The next effective treatments recorded were open pollination (2.56) and a colony of *Trigona* sp. covered with net (2.46).

Five days after sprays, maximum number of bee visited in the treatment of sugar solution spray 5% (2.78). However, one framed *A. mellifera* colony covered with net (2.42), jaggery solution spray 5% (2.32), a colony of *Trigona* sp. covered with net (2.29) and open pollination (2.29) were found at par with each other.

On seven days after sprays, maximum number of bee visits were found in the treatment of one framed *A. mellifera* colony covered with net (2.46) and it was at par with jaggery solution spray 5% (2.09), sugar solution spray 5% (2.06). The next effective treatments recorded were a colony of *Trigona* sp. covered with net (1.93) and open pollination (1.84) (Plate VII).

Here, maximum number of bee visited in the sugar and jaggery sprays. It may be due to presence sugary substances on the crop which attracted more honey bees due to its strong olfactory receptors.

4.1.3.4 Bee visitation during *rabi,* 2018

First spray

Observations were recorded on *A. mellifera* L. and *Trigona* sp. visitation on onion umbels from five per cent flowering periods during *rabi,* 2018 (Table 4.14).

The observations recorded one day before the first spray indicated that number of bees visited to onion umbels ranged from 0.00 to 3.22 bees/ m^2/ 2 minutes which differed significantly among the treatments.

One day after the first spray, maximum number of honey bees visited in the treatment of jaggery solution spray 5% (4.08 bees/ m^2/ 2 minutes) and it was at par with treatment of sugar solution spray 5% (3.78), one framed *A. mellifera* colony covered with net (3.38) and open pollination (3.22). Moreover, open pollination treatment showed equal visitation of bees with a colony of *Trigona* sp. covered with net (2.46).

After three days of the first spray, maximum number of honey bees visited in the treatment of sugar solution spray 5% (3.95) and it was at par with treatment of jaggery solution spray 5% (3.70), one framed *A. mellifera* colony covered with net (3.70), a colony *Trigona* sp. covered with net (2.96) and open pollination (2.67). However, treatment open pollination showed equal visitation of honey bees with a colony *Trigona* sp. covered with net.

Five days after the first spray, maximum number of honey bees visited in the treatment of one framed *A. mellifera* colony covered with net (2.96) and it was at par with treatment of sugar solution spray 5% in open plots (2.70), jaggery solution spray 5% in open plots (2.67), a colony *Trigona* sp. covered with net (2.22). However, a colony of *Trigona* sp. covered with net showed equal visitation of honey bees with open pollination (1.84).

On seven days after spray, maximum number of honey bees visited in the treatment of one framed *A. mellifera* colony covered with net (2.70) and it was at par with treatment of jaggery solution spray 5% in open plot (2.46), sugar solution spray 5% in open plot (2.46) and a colony *Trigona* sp. covered with net (1.96). However, a colony *Trigona* sp. covered with net showed equal visitation of honey bees with open pollination (1.52).

Table 4.14: Bee visits after first spray on umbels of onion during *rabi*, 2018

Sr. No.	Treatments	No. of bees/ m^2 / 2 minutes*				
		Before spray	1	3	5	7
T_1	Open pollination (OP)	1.72 (2.46)	1.93 (3.22)	1.78 (2.67)	1.53 (1.84)	1.42 (1.52)
T_2	Net covered plants	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_3	One framed *A. mellifera* colony covered with net	1.86 (2.96)	1.97 (3.38)	2.05 (3.70)	1.86 (2.96)	1.79 (2.70)
T_4	*Trigona* sp. colony covered with net	1.65 (2.22)	1.72 (2.46)	1.86 (2.96)	1.65 (2.22)	1.57 (1.96)
T_5	Sugar solution spray (5%) in open plot	1.86 (2.96)	2.07 (3.78)	2.11 (3.95)	1.79 (2.70)	1.72 (2.46)
T_6	Jaggery solution spray (5%) in open plot	1.93 (3.22)	2.14 (4.08)	2.05 (3.70)	1.78 (2.67)	1.72 (2.46)
S. Em. ±		0.07	0.07	0.08	0.07	0.08
C.D. at 5%		0.21	0.21	0.24	0.21	0.24
C.V. %		8.23	7.88	8.51	8.47	10.14

Note: Figures in the parentheses are retransformed values and those outside are $\sqrt{x + 0.5}$ transformed values

* DAS= Days after spray

4.1.3.5 Bee visitation during *rabi,* 2018

Second spray

Observations were recorded on *A. mellifera* L. and *Trigona* sp. visitation on onion umbels from five per cent flowering periods during *rabi,* 2018 (Table 4.15).

The observations recorded one day before the first spray indicated that number of bees visited to onion umbels ranged from 0.00 to 2.46 bees/ m^2/ 2 minutes and differed significantly among the treatments. Following a day after the second spray maximum number of honey bees visited in the treatment of sugar solution spray 5% (3.95 bees/ m^2/ 2 minutes) and it was at par with treatment of jaggery spray 5% (3.78) and one framed *A. mellifera* colony covered with net (3.26). Moreover, a treatment of *Trigona* sp. colony covered with net (2.96) showed equal visitation of honey bees with open pollination (1.52).

Three days after the second spray, maximum number of honey bees visited in the treatment of jaggery solution spray 5% (2.96) and it was at par with treatment of one framed *A. mellifera* colony covered with net (2.70), sugar solution spray 5% (2.70), open pollination (2.39) and a *Trigona* sp. colony covered with net (2.22).

After five days of second spray, maximum number of honey bees visited in the treatment of one framed *A. mellifera* colony covered with net (2.67) and it was at par with treatment of jaggery solution spray 5% (2.60), sugar solution spray 5% (2.16), open pollination (2.12) and a *Trigona* sp. colony covered with net (1.96).

On seven days after second spray, maximum number of honey bees visited in the treatment of one framed *A. mellifera* colony covered with net (1.96), sugar solution spray 5% (1.96), a *Trigona* sp. colony covered with net (1.96) and jaggery solution spray 5% (1.84). Moreover, a treatment of *Trigona* sp. colony covered with net showed equal visitation of honey bees with open pollination (1.72).

Table 4.15: Bee visits after second spray on umbels of onion during *rabi*, 2018

Sr. No.	Treatments	No. of bees/ m^2 / 2 minutes				
		Before spray	1	3	5	7
T_1	Open pollination (OP)	1.52 (1.81)	1.42 (1.52)	1.70 (2.39)	1.62 (2.12)	1.49 (1.72)
T_2	Net covered plants	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_3	One framed *A. mellifera* colony covered with net	1.72 (2.46)	1.94 (3.26)	1.79 (2.70)	1.78 (2.67)	1.57 (1.96)
T_4	*Trigona* sp. colony covered with net	1.49 (1.72)	1.86 (2.96)	1.65 (2.22)	1.57 (1.96)	1.57 (1.96)
T_5	Sugar solution spray (5%) in open plot	1.57 (1.96)	2.11 (3.95)	1.79 (2.70)	1.63 (2.16)	1.57 (1.96)
T_6	Jaggery solution spray (5%) in open plot	1.65 (2.22)	2.07 (3.78)	1.86 (2.96)	1.72 (2.60)	1.53 (1.84)
S. Em. ±		0.08	0.07	0.09	0.08	0.07
C.D. at 5%		0.23	0.200	0.27	0.23	0.213
C.V. %		10.42	7.02	11.29	9.56	9.63

Note: Figures in the parentheses are retransformed values and those outside are $\sqrt{x + 0.5}$ transformed values

* DAS= Days after spray

Table 4.16: Bee visits in onion during *rabi*, 2018*

Sr. No.	Treatments	No. of bees/ m^2 /2 minutes**			
		1	3	5	7
T_1	Open pollination (OP)	2.01 (3.54)	1.91 (3.15)	1.79 (2.70)	1.61 (2.09)
T_2	Net covered plants	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_3	One framed *A. mellifera* colony covered with net	2.02 (3.58)	1.95 (3.30)	1.82 (2.81)	1.64 (2.19)
T_4	*Trigona* sp. colony covered with net	1.79 (2.70)	1.75 (2.56)	1.61 (2.09)	1.57 (1.96)
T_5	Sugar solution spray (5%) in open plot	2.03 (3.62)	1.92 (3.19)	1.75 (2.56)	1.64 (2.19)
T_6	Jaggery solution spray (5%) in open plot	2.05 (3.70)	1.93 (3.22)	1.83 (2.85)	1.65 (2.22)
S. Em. ±		0.04	0.06	0.05	0.05
C.D. at 5%		0.13	0.18	0.15	0.15
C.V. %		7.50	10.09	8.98	10.23

Note: Figures in the parentheses are retransformed values and those outside are $\sqrt{x+0.5}$ transformed values

*Mean of two sprays

** DAS= Days after spray

4.1.3.6 Pooled over sprays during *rabi*, 2018

The data on pooled over sprays indicated that days after sprays were recorded maximum number of bee visit 3.62 bees/ m^2/ 2 minutes during different periods from 1, 3, 5 and 7 days after spray. Furthermore, visit of bee showed declined with number of days increased of subsequent sprays (Table 4.16).

One day after sprays, maximum number of honey bees visited in the treatment of one framed *A. mellifera* colony covered with net (3.58 bees/ m^2/ 2 minutes) and it was at par with treatment of jaggery solution spray 5% (3.70), sugar solution spray 5% (3.62). Moreover, a treatment of *Trigona* sp. colony covered with net showed minimum visitation of honey bees (2.70).

After three days of sprays, maximum number of honey bees visited in the treatment of one framed *A. mellifera* colony covered with net (3.30) and it was at par with treatment of jaggery solution spray 5% (3.22), sugar solution spray 5% (3.19), open pollination (3.15) and a *Trigona* sp. colony covered with net (2.56).

Maximum number of honey bees visits were found in the treatment of jaggery solution spray 5% (2.85) in five days after sprays and it was at par with treatment of one framed *A. mellifera* colony covered with net (2.81), open pollination (2.70) sugar solution spray 5% (2.56). Minimum number of bee visits showed in the treatments of a *Trigona* sp. colony covered with net (2.09).

On seven days after sprays, maximum number of honey bees visited in the treatment of jaggery solution spray 5% (2.22) and it was at par with treatment of one framed *A. mellifera* colony covered with net (2.19), sugar solution spray 5% (2.19), open pollination (2.09) and with a treatment of *Trigona* sp. colony covered with net (1.96) (Plate VIII).

It is clearly showed that sugar and jaggery like phagostimulants attracted more bees in onion crop. So, maximum bee visits were found in the treatments of sugar and jaggery spray.

4.1.4 Effect of bees pollination on various qualitative and quantitative characters

The results of the experiment conducted during *rabi*, 2017 and 2018 are presented here:

The data on various quantitative characters of onion during *rabi,* 2017 indicated that the treatment of sugar solution five per cent was found significantly superior by showing umbel weight (382.50 g/ umbel), weight of thousand seeds (5.85 gm), total number of seeds/umbel (4930) and total seed yield (1425.50 kg/ ha). Treatment of jaggery solution five per cent spray was found next effective treatment umbel weight (365 g/ umbel), weight of thousand seeds (5.25 gm), total number of seeds/umbel (4820) and total seed yield (1420.00 kg/ ha). However, it was at par with the treatment of one framed *A. mellifera* colony covered with net which showed umbel weight (345.00 g/ umbel), weight of thousand seeds (4.65 gm), total number of seeds/umbel (4525) (Plate XI) and total seed yield by 1380.00 kg/ ha. The treatment of open pollination and net covered plants were found less effective and showed lower umbel weight (315.00 and 295.00 g/ umbel), weight of thousand seeds (4.35 and 4.00 gm), total number of seeds/umbel (4525 and 4400) and total seed yield (1352.50 and 1262.50 kg/ ha) (Table 4.17).

Various qualitative characters of onion recorded during *rabi*, 2017 indicated that the treatment of sugar solution five per cent was found significantly superior by showing wrinkled seeds (11.00%) and gemination (91%). Treatment of jaggery solution five per cent was found next effective by indicating wrinkled seeds (10.75%) and gemination (89.25%). However, it was found at par with the treatment of one framed *A. mellifera* colony covered with net showed wrinkled seeds (13.25%) and gemination (82.75%) (Plate X). The treatment of open pollination and net covered plants were found less effective and showed lower wrinkled seeds (15.00 and 16.10%) and gemination (78.50 and 75.25%), respectively (Table 4.18).

The data on various quantitative characters of onion crop during *rabi*, 2018 indicated that the treatment of sugar solution five per cent was found significantly superior by showing umbel weight (395.00 g/ umbel), weight of thousand seeds (5.55 gm), total number of seeds/umbel (4835) and total seed yield (1432.50 kg/ ha). Treatment of jaggery solution five per cent was found next effective treatment by

indicating umbel weight (382 g/ umbel), weight of thousand seeds (5.78 gm), total number of seeds/umbel (4865) and total seed yield (1440.00 kg/ ha). However, it was at par with the treatment of one framed *A. mellifera* colony covered with net by recording umbel weight (360.00 g/ umbel), weight of thousand seeds (5.53 gm), total number of seeds/umbel (4620) and total seed yield (1400.00 kg/ ha). The treatment of open pollination and net covered plants were found less effective and showed lower umbel weight (340.00 and 290.00 g/ umbel), weight of thousand seeds (4.45 and 4.10 gm), total number of seeds/umbel (4610 and 4420) and total seed yield (1367.50 and 1282.50 kg/ ha) (Table 4.19).

It was found from the data (Table 4.20) on various qualitative characters of onion indicated that the treatment of sugar solution five per cent was found significantly superior by showing wrinkled seeds (11.75%) and gemination (91.75%). Treatment of jaggery solution five per cent was found next effective by indicating wrinkled seeds (11.25%) and gemination (90.35%). However, it was found at par with the treatment of one framed *A. mellifera* colony covered with net which showed wrinkled seeds (14.75%) and gemination (83.25%). The treatment of open pollination and net covered plants were found less effective and showed more wrinkled seeds (15.50 and 16.30%) and lower gemination (79.75 and 78.00%), respectively.

Table 4.17: Effect of bees pollination on quantitative characters of onion during *rabi*, 2017

Sr. No.	Treatments	Umbel weight (g/ umbel)	Weight of 1000 seeds (g)	Total number of seeds/ umbel	Total seed yield (kg/ ha)
T_1	Open pollination (OP)	315.00	4.35	4525	1352.50
T_2	Net covered plants	295.00	4.00	4400	1262.50
T_3	One framed *A. mellifera* colony covered with net	345.00	4.65	4525	1380.00
T_4	*Trigona* sp. colony covered with net	372.50	4.35	4520	1340.00
T_5	Sugar solution spray (5%) in open plot	382.50	5.25	4820	1420.00
T_6	Jaggery solution spray (5%) in open plot	365.00	5.85	4930	1425.50
S. Em. ±		21.13	0.32	25.27	23.56
C.D. at 5%		63.67	0.97	76.16	71.01
C.V. %		13.78	15.71	13.07	13.68

Table 4.18: Effect of bees pollination on qualitative characters of onion during *rabi*, 2017

Sr. No.	Treatments	Wrinkled seed (%)	Germination (%)
T_1	Open pollination (OP)	15.00	78.50
T_2	Net covered plants	16.10	75.25
T_3	One framed *A. mellifera* colony covered with net	13.25	82.75
T_4	*Trigona* sp. colony covered with net	14.25	87.75
T_5	Sugar solution spray (5%) in open plot	11.00	91.00
T_6	Jaggery solution spray (5%) in open plot	10.75	89.25
S. Em. ±		2.83	2.22
C.D. at 5%		7.58	6.70
C. V. %		9.35	6.05

Table 4.19: Effect of bees pollination on quantitative characters of onion during *rabi*, 2018

Sr. No.	Treatments	Umbel weight (g/ umbel)	Weight of 1000 seeds (g)	Total number of seeds/ umbel	Total seed yield (kg/ ha)
T_1	Open pollination (OP)	340.00	4.45	4610	1367.50
T_2	Net covered plants	290.00	4.10	4420	1282.50
T_3	One framed *A. mellifera* colony covered with net	360.00	5.53	4620	1400.00
T_4	*Trigona* sp. colony covered with net	380.00	5.07	4610	1370.00
T_5	Sugar solution spray (5%) in open plot	395.00	5.55	4835	1432.50
T_6	Jaggery solution spray (5%) in open plot	382.00	5.78	4865	1440.00
S. Em. ±		18.63	0.36	23.31	21.89
C.D. at 5%		56.13	1.07	70.25	65.96
C.V. %		11.49	15.91	11.37	11.98

Table 4.20: Effect of bees pollination on qualitative characters of onion during *rabi*, 2018

Sr. No.	Treatments	Wrinkled seed (%)	Germination (%)
T_1	Open pollination (OP)	15.50	79.75
T_2	Net covered plants	16.30	78.00
T_3	One framed *A. mellifera* colony covered with net	14.75	83.25
T_4	*Trigona* sp. colony covered with net	13.20	90.00
T_5	Sugar solution spray (5%) in open plot	11.75	91.75
T_6	Jaggery solution spray (5%) in open plot	11.25	90.35
S. Em. ±		2.51	1.95
C.D. at 5%		8.52	5.87
C. V. %		10.41	5.22

4.2 Seasonal activities of *Apis mellifera* L. and *Trigona* sp.

Seasonal activities of honey bees were noted on sunflower and onion by raising of crop without any application of attractants. One square meter area was randomly selected from both the plots during their crop periods. Observations were recorded for first 2 minutes of every two hours during 08:00 to 10:00, 10:00 to 12:00, 12:00 to 14:00, 14:00 to 16:00 and 16:00 to 18:00 hrs by using a stopwatch. Observations were taken at weekly interval throughout flowering season. The data were recorded and statistically analyzed.

The observations of honey bees activities were started from flowering periods till maturity of crops. The data showed that there was no any activity of bees at 6.00 hrs in the morning. The activities of honey bees started at 08.00 hrs (0.05 to 0.75 bees/ m^2/ 2 minutes) in the morning. Thereafter, activities of honey bees reached to its peak during 10.00 to 12.00 hrs (1.75 to 2.25) in the months of November and December in sunflower crop. These activities showed decline as time passed and lower activities of honey bees were found at 16.00 to 18.00 hrs. Here, on first and third week of December, there was no any activities of honey bees due to adverse climatic conditions (Table 4.21).

The same trend was found in sunflower during *rabi,* 2017 (Table 4.22). The results showed that maximum activities of honey bees were found during 10.00 to 12.00 hrs (0.50 to 3.00 bees/m^2/2 minutes). Here, there was no any activities of honey bees due to adverse climatic conditions on 4^{th} week of December and 1^{st} week of January.

Sreedevi and Jadhav (2010) reported maximum foraging activities of pollinators during 10.00 hrs and 11.00 hrs in sunflower crop. Studies were conducted by Ali *et al.* (2015) indicated that the peak activities of honey bees were recorded at 12:00 and 02:00 pm while minimum activities were recorded at 08:00 am and 04:00 pm.

Table 4.21: Seasonal activities of *Apis mellifera* L. in sunflower during *kharif*, 2017

Month and week		SMW	Date of observation	Bee activity/m^2/ 2 minutes				
				8.00 to 10.00	**10.00 to 12.00**	**12.00 to 14.00**	**14.00 to 16.00**	**16.00 to 18.00**
November, 2017	5	48	28/11/2017	0.06 ± 0.02 (0.75)	2.56 ± 0.03 (1.75)	1.06 ± 0.015 (1.25)	1.00 ± 0.00 (0.50)	1.00 ± 0.00 (0.50)
December, 2017	1	49	05/12/2017	-	-	-	-	-
	2	50	12/12/2017	1.00 ± 0.00 (0.50)	4.56 ± 0.04 (2.25)	3.50 ± 0.02 (2.00)	2.56 ± 0.01 (1.75)	1.75 ± 0.013 (1.50)
	3	51	19/12/2017	-	-	-	-	-

SMW: Standard Meteorological Week

Table 4.22: Seasonal activities of *Apis mellifera* L. in sunflower during *rabi*, 2017-18

Month and week		**SMW**	**Date of observations**	**Bee activity/m^2/ 2 minutes**				
				8.00 to 10.00	**10.00 to 12.00**	**12.00 to 14.00**	**14.00 to 16.00**	**16.00 to 18.00**
December, 2017	3	50	14/12/2017	1.06 ± 0.01 (1.25)	8.50 ± 0.06 (3.00)	4.56 ± 0.04 (2.25)	3.50 ± 0.02 (2.00)	2.56 ± 0.01 (1.75)
	4	51	21/12/2017	-	-	-	-	-
	5	52	28/12/2017	1.00 ± 0.00 (0.50)	4.56 ± 0.03 (2.25)	3.50 ± 0.02 (2.00)	1.06 ± 0.01 (1.25)	1.00 ± 0.00 (0.50)
January, 2018	1	1	04/01/2018	-	-	-	-	-

SMW: Standard Meteorological Week

Seasonal activities of honey bees were found maximum during flowering period of crop. The peak activities were recorded on 10.00 to 12.00 hrs (0.50 to 3.00 bees/ m^2/ 2 minutes) which slowly declined as day passed (Table 4.23) in onion crops during *rabi*, 2017.

The same trend was found in onion crop during *rabi,* 2018 (Table 4.24). The results showed that maximum activities of honey bees were found during 10.00 to 12.00 hrs (0.50 to 3.00 bees/m^2/2 minutes). Studies were conducted by Ali *et al.* (2015) in Pakistan and reported minimum activities were recorded at 08:00 am and 04:00 pm. At University of agricultural science, Banglore, Reddy *et al.* (1993) reported that bees were active throughout the whole day from 07.00 to 18.00 hrs on sunflower crops. The peak activity of bees was observed at 09:00 hrs. Mupade *et al.* (2009) studied relative abundance of different pollinators on onion in Maharashtra and reported that honey bees started visiting the crop at 8.00 hrs, and declined slowly during 16.00-18.00 hrs. These are agreement with the present findings.

Table 4.23: Seasonal activities of *Trigona* sp. in onion during *rabi*, 2017

Month and week		SMW	Date of observations	Bee activity/m^2/ 2 minutes				
				08.00 to 10.00	**10.00 to 12.00**	**12.00 to 14.00**	**14.00 to 16.00**	**16.00 to 18.00**
March, 2017	4	18	20/03/2017	-	-	-	-	-
	5	19	27/03/2017	1.06 ± 0.01 (1.25)	8.50 ± 0.04 (3.00)	4.56 ± 0.08 (2.25)	2.56 ± 0.03 (1.75)	1.00 ± 0.00 (1.00)
April, 2017	1	20	03/04/2017	1.00 ± 0.00 (0.50)	4.56 ± 0.08 (2.25)	3.50 ± 0.02 (2.00)	1.75 ± 0.01 (1.50)	1.00 ± 0.00 (0.50)
	2	21	10/04/2017	1.00 ± 0.00 (0.50)	3.50 ± 0.02 (2.00)	2.56 ± 0.03 (1.75)	1.06 ± 0.00 (1.25)	1.00 ± 0.00 (0.50)
	3	22	17/04/2017	-	-	-	-	-
	4	23	24/04/2017	-	-	-	-	-

SMW: Standard Meteorological Week

Table 4.24: Seasonal activities of *Trigona* sp. in onion during *rabi*, 2018

Month and week		SMW	Date of observations	Bee activity/m^2/ 2 minutes				
				08.00 to 10.00	10.00 to 12.00	12.00 to 14.00	14.00 to 16.00	16.00 to 18.00
January, 2018	4	12	22/01/2017	-	-	-	-	-
	5	13	29/01/2017	1.00 ± 0.00 (0.50)	4.56 ± 0.03 (2.25)	3.50 ± 0.02 (2.00)	1.75 ± 0.01 (1.50)	1.00 ± 0.00 (0.50)
February, 2018	1	14	05/02/2018	1.50 ± 0.01 (1.75)	8.50 ± 0.06 (3.00)	7.06 ± 0.05 (2.75)	3.50 ± 0.02 (2.00)	1.00 ± 0.00 (0.50)
	2	15	12/02/2018	1.00 ± 0.00 (0.50)	7.06 ± 0.05 (2.75)	3.50 ± 0.02 (2.00)	1.75 ± 0.01 (1.50)	1.00 ± 0.00 (0.50)
	3	16	19/02/2018	-	-	-	-	-
	4	17	26/02/2018	-	-	-	-	-

SMW: Standard Meteorological Week

Table 4.25: Correlation between weather parameters and bee visits in sunflower during *kharif*, 2017

Weather parameters	Correlation coefficient (r)
Bright sunshine hours (h/day)	0.792*
Wind speed (kmph)	-0.404*
Maximum temperature (°C)	-0.506**
Minimum temperature (°C)	0.289*
Morning relative humidity (%)	0.679*
Evening relative humidity (%)	0.240

Note: * Significant at 0.05 level
** Significant at 0.01 level

Table 4.26: Correlation between weather parameters and bee visits in sunflower during *rabi*, 2017-18

Weather parameters	Correlation coefficient (r)
Bright sunshine hours (h/day)	0.803*
Wind speed (kmph)	-0.484*
Maximum temperature (°C)	-0.596**
Minimum temperature (°C)	0.290*
Morning relative humidity (%)	0.847*
Evening relative humidity (%)	0.331

Note: * Significant at 0.05 level
** Significant at 0.01 level

The bees were active from 08.00 hrs in the morning. Number of bee visits showed significant positive correlation with bright sunshine hour (r=0.792) and minimum temperature (r=0.289), morning relative humidity (r=0.679) and evening relative humidity (r=0.240), while bee visits showed negative correlation with wind speed (r= -0.404) and highly negative with maximum temperature (r= -0.506) during *kharif,* 2017 in sunflower. These results indicated that bee visits were highly fluctuated with weather conditions (Table 4.25).

The data (Table 4.26) on number of bee visits showed significant positive correlation with bright sunshine hour (r=0.803) and minimum temperature (r=0.290), morning relative humidity (r=0.847; p<.0.01) and evening relative humidity (r=0.331), while bee visits were showed negative correlation with wind speed (r= -0.484) and highly negative correlation with maximum temperature (r= -0.596) during *rabi*, 2017 in sunflower crop. These results indicated that bee visits were highly fluctuate with weather conditions.

The data on weather parameters showed significant positive correlation with bright sunshine hour (r=0.847) and minimum temperature (r=0.382), morning relative humidity (r=0.686; p<.0.01) and evening relative humidity (r=0.980), while bee visits were showed negative correlation with wind speed (r= -0.452) and highly negative correlation with maximum temperature (r= -0.574) during *rabi*, 2017 in onion crop. These results indicated that bee visits were highly fluctuate with weather conditions (Table 4.27).

There was increased visitation of bees on sunflower capitula when the flowering period coincided with lower temperatures and higher relative humidity. In certain situations, weather conditions helped for opening on capitula flowers, flight behavior and bee visitation during the experimental period.

Table 4.27: Correlation between weather parameters and bee visits in onion during *rabi*, 2017

Weather parameters	Correlation coefficient (r)
Bright sunshine hours (h/day)	0.847*
Wind speed (kmph)	-0.452*
Maximum temperature (°C)	-0.574**
Minimum temperature (°C)	0.382*
Morning relative humidity (%)	0.686*
Evening relative humidity (%)	0.980

Note: * Significant at 0.05 level
** Significant at 0.01 level

Table 4.28: Correlation coefficient (r) between weather parameters and bee visits in onion during *rabi*, 2018

Weather parameters	Correlation coefficient (r)
Bright sunshine hours (h/day)	0.803*
Wind speed (kmph)	-0.401*
Maximum temperature (°C)	-0.568**
Minimum temperature (°C)	0.117*
Morning relative humidity (%)	0.622*
Evening relative humidity (%)	0.206

Note: * Significant at 0.05 level
** Significant at 0.01 level

During *rabi*, 2018 data on weather parameters showed significant positive correlation with bright sunshine hour (r=0.803) and minimum temperature (r=0.117), morning relative humidity (r=0.622) and evening relative humidity (r=0.206), while bee visits were showed negative correlation with wind speed (r= -0.401) and highly negative correlation with maximum temperature (r= -0.568) during *rabi*, 2018 in onion. These results indicated that bee visits were highly fluctuate with weather conditions (Table 4.28).

According to Sreedevi and Jadhav (2010), honey bee activities was influenced by weather factors like temperature and relative humidity. Very low temperatures and very high humidity were not favourable for honey bee activities. These are in agreement with the present investigations.

5. SUMMARY AND CONCLUSION

Investigations on role of honey bees for increasing seed production were carried out at Department of Entomology, B. A. College of Agriculture, Anand Agricultural University, Anand (Gujarat). The foraging and seasonal activities of honey bees were carried out for sunflower at Agronomy farm, Anand Agricultural University, Anand during *kharif*, 2017 and *rabi*, 2017-18 and for onion at Main Vegetable Research Station, AAU, Anand during *rabi*, 2017 and *rabi*, 2018.

The experiments were laid out in randomized complete block design with six treatments *viz.*, open pollination, pollination without insects or net covered plants, one framed *Apis mellifera* L. colony and *Trigona* sp. colony covered with nets, five percent solutions of sugar and jaggery in open plots during flowering periods. The results obtained from present investigations are summarized here.

Effect of bees pollination on various qualitative and quantitative characters

Sunflower

Results of noted data showed that higher bees visits found at one and three days after sprays (0.00 to 3.92 bees/ five capitula/ two minute) as compared to five days after spray in *kharif*, 2017. In *rabi*, 2017-18 maximum bee visits were reported (0.00 to 3.96 no. of bees/ five capitula/ two minute). Moreover, maximum number of bee visits were found in the treatments of sugar and jaggery five per cent spray solutions in open plot which found at par with the treatments of one framed *Apis mellifera* L. colony covered with net, *Trigona* sp. colony covered with net and open pollination. Also, there was no any bee visit reported in the treatment of pollination without insects in both the season.

Different eleven qualitative and quantitative characters were recorded at harvest from sunflower crop for both the year 2017 and 2018. All the characters *viz.*, yield, head diameter, head weight, number of filled seeds per head, weight of thousand seeds and seeds weight per head, total number of seeds/ umbel, wrinkled seeds (%) and oil per cent, germination (%) and seed setting (%) were found superior in the treatment of sugar and jaggery solution five per cent sprays as well as in one framed *A. mellifera* L. colony covered with net. Remaining treatments were found inferior and at par with each other.

The data on various quantitative characters of sunflower crop during *kharif*, 2017 indicated that the treatment of jaggery solution five per cent was found significantly superior by showing head diameter (36.25 cm), head weight (1670 gm), number of filled seeds per head (1975), weight of thousand seeds (65 gm), seed weight per head (640 gm), total number of seeds/ head (1985) and yield (1530 kg/ ha) and it was at par with sugar solution five per cent by indicating head diameter (34.75 cm), head weight (1650 gm), number of filled seeds per head (1930), weight of thousand seeds (60 gm), seed weight per head (610 gm), total number of seeds/ head (1980) and yield (1520 kg/ ha) and one framed *A. mellifera* colony covered with net which showed head diameter (33.75 cm), head weight (1660 gm), number of filled seeds per head (1860), weight of thousand seeds (55 gm), seed weight per head (585 gm), total number of seeds/ head (1840) and yield (1525 kg/ ha).

The data on various qualitative characters of sunflower crop indicated that the treatment of jaggery solution five per cent was found significantly superior in respect to wrinkled seeds (13%) and oil per cent (42%) while more germination (91%) and seed setting (92%) were found in the treatment of sugar solution five per cent as recorded germination (95%) and seed setting (96%) and it was at par with sugar solution five per cent was found next effective treatment recording wrinkled seeds (10%) and oil per cent (40%). Results found at par with the treatment of one framed *A. mellifera* colony covered with net. It is clearly indicated that due to application of sugar and jaggery like phagostimulants, more number of bees attracted and lead to better aforesaid characters.

The data on various quantitative characters of sunflower crop during *rabi*, 2017 indicated that the treatment of jaggery solution five per cent was found significantly superior by showing head diameter (39.75 cm), head weight (1720 gm), number of filled seeds per head (1965), weight of thousand seeds (68 gm), seed weight per head (625 gm), total number of seeds/ head (1990) and yield (1610 kg/ ha). Treatment of sugar solution five per cent was found next effective treatment by indicating head diameter (38.25 cm), head weight (1680 gm), number of filled seeds per head (1950), weight of thousand seeds (62 gm), seed weight per head (630 gm), total number of seeds/ head (1995) and yield (1640 kg/ ha).

Various qualitative characters of sunflower crop showed that the treatment of jaggery solution five per cent was found significantly superior by recording wrinkled seeds (11%) and oil per cent (41.5%) while more germination (90%) and seed setting

(91%) were found in the treatment of sugar solution five per cent as recorded germination (92%) and seed setting (94%). Treatment of sugar solution five per cent was found next effective treatment recording wrinkled seeds (12.5%) and oil per cent (43%). It is clearly indicated that due to application of sugar and jaggery like phagostimulants, more number of bees attracted and lead to better quality and quantity of sunflower crop.

The data on seed setting (%), number of filled seeds per head, weight of thousand seeds (g), seed weight per head (g) and yield (kg/ ha) were higher in the plots treated with on which sugar and jaggery as well as one framed *A. mellifera* colony covered with net, a colony of *Trigona* sp. covered with net and open pollination. This was due to the effect of honey bees as efficient pollinators of the sunflower.

Effect of bees pollination on various qualitative and quantitative characters

Onion

Data on bee visits were recorded in onion during *rabi,* 2017 and 2018. The noted data were indicated that higher bee visits found at one and three days after sprays 2.98 bees/ m^2/ two minute as compared to five days after spray in *rabi*, 2017. In *rabi*, 2018 maximum bee visits were reported during 3.31 bees/ m^2/ two minute. Moreover, maximum number of bee visits were found in the treatments of sugar and jaggery five per cent spray solutions in open plot which found at par with treatments of one framed *A. mellifera* L. colony covered with net, *Trigona* sp. colony covered with net and open pollination.

Different six characters were recorded like total seed yield/plot, umbel weight, weight of thousand seeds, seed number, wrinkled seeds (%) and germination (%). The data on various quantitative characters of onion during *rabi*, 2017 indicated that the treatment of sugar solution five per cent was found superior by showing umbel weight (382.50 g/ umbel), weight of thousand seeds (5.85 gm), total number of seeds/umbel (4930) and total seed yield (1425.50 kg/ ha) and it was at par with jaggery solution five per cent spray umbel weight (365 g/ umbel), weight of thousand seeds (5.25 gm), total number of seeds/umbel (4820) and total seed yield (1420.00 kg/ ha). Various qualitative characters of onion indicated that the treatment of sugar solution five per cent was found significantly superior by showing wrinkled seeds (11.00%) and gemination (91%) and it was at par with jaggery solution five per cent was found next effective by indicating

wrinkled seeds (10.75%) and gemination (89.25%). It is clearly indicated that sugar and jaggery solution five per cent found effective among all remaining ones.

Various quantitative characters of onion crop during *rabi,* 2018 indicated that the treatment of sugar solution five per cent was found superior by showing umbel weight (395.00 g/ umbel), weight of thousand seeds (5.55 gm), total number of seeds/umbel (4835) and total seed yield (1432.50 kg/ ha) and it was at par with jaggery solution five per cent by indicating umbel weight (382 g/ umbel), weight of thousand seeds (5.78 gm), total number of seeds/umbel (4865) and total seed yield (1440.00 kg/ ha). The data on various qualitative characters of onion indicated that the treatment of sugar solution five per cent was found significantly superior by showing wrinkled seeds (11.75%) and gemination (91.75%). Treatment of jaggery solution five per cent was found next effective by indicating wrinkled seeds (11.25%) and gemination (90.35%). It is clearly indicated that more bee visits lead to better qualitative and quantitative characters of onion. Moreover, it showed similar results with the treatments of one framed *A. mellifera* colony covered with net, a colony of *Trigona* sp. covered with net and open pollination. This could be attributed to the effect of honey bees as efficient pollinators of onion.

Seasonal activities of *Apis mellifera* L. and *Trigona* sp.

Seasonal activities of honey bees were noted on sunflower and onion by raising of crop without any applications of attractants. One square meter area was randomly selected from both the plots during their crop periods. Observations were recorded for first two min of every two hours during 08:00 to 10:00, 10:00 to 12:00, 12:00 to 14:00, 14:00 to 16:00 and 16:00 to 18:00 hrs by using a stopwatch. Observations were taken at weekly interval throughout flowering season.

The observations of honey bee activities of honey bees were started from flowering periods till maturity of crops. The data showed that there was no any activity of bees at 6.00 hrs in the morning. The seasonal activities of honey bees started at 08.00 hrs (0.05 to 0.75 bees/ m2/ two min) during flowering period. Thereafter, activities of honey bees reached to its peak during 10.00 to 12.00 hrs (1.75 to 2.25) in the months of November and December in sunflower crop. These activities showed decline as time passed and lower activities of honey bees were found at 16.00 to 18.00 hrs. Here, on first and third week of December, there was no any activity of honey bees found due to adverse climatic conditions. Honey bee activity was influenced by weather factors like

temperature and relative humidity. Also, same trend of seasonal activities of honey bees were found in onion.

It is concluded that honey bees are more attracted towards sugar and jaggery like phagostimulants. They have very good senses of olfactory receptors. But, after three days of sprays, the influences of phagostimulant declined. Moreover, bee visits fluctuated with weather parameters. Low temperatures and high humidity were not favourable for honey bee activities. Therefore, it is clearly indicated that bees played a major role in pollination of sunflower and onion.

In nutshell, treatments of sugar and jaggery solution five per cent spray showed similar results with the treatments of one framed *Apis mellifera* L. colony covered with net, *Trigona* sp. colony covered with net and open pollination. So, more bee visits leads to better qualitative and quantitative characters of sunflower and onion.

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*-original paper not seen

APPENDIX

Appendix : Observations of meteorological data of different standard weeks during 2017 and 2018

SMW	RF (mm)	BSS (h/day)	WS (kmph)	MAX T (°C)	MIN T (°C)	RH1 (%)	RH2 (%)
1	0	8.70	2.70	27.17	9.43	87.29	39.92
2	0	6.19	3.39	27.46	13.19	77.29	40.29
12	0	9.90	4.10	37.30	18.80	71.00	26.00
13	0	10.00	3.70	40.80	20.80	64.00	20.00
14	0	10.00	6.50	37.30	18.60	88.00	29.00
15	0	10.40	3.70	41.20	18.80	49.00	9.00
16	0	10.60	6.40	40.50	22.80	72.00	22.00
17	0	10.60	5.60	37.50	21.70	78.00	31.00
18	0	10.40	4.60	40.50	22.90	73.00	25.00
19	0	11.2	5.20	41.60	24.8	80.00	25.00
20	0	10.7	6.20	41.10	25.0	70.00	30.00
21	3.4	11.1	6.50	40.10	25.60	76.00	39.00
22	0	9.7	8.20	39.00	28.00	81.00	46.00
23	2.0	9.0	8.4	39.00	27.4	82.00	85.00
48	0	9.33	2.03	31.89	12.47	87.52	31.02
49	5.4	2.73	6.39	24.90	16.13	85.80	65.21
50	0	6.66	2.95	28.71	13.89	86.75	45.22
51	0	4.41	5.70	27.16	14.33	71.14	41.56
52	0	7.95	2.36	25.15	8.53	77.63	31.36

Note: RF=Rainfall, BSS=Bright Sunshine Hour, WS=Wind Speed, MAX T=Maximum Temperature, MIN T=Minimum Temperature, RH1=Morning Relative Humidity and RH2= Evening Relative Humidity

C E R T I F I C A T E

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