

**IMPACT OF INSECT POLLINATION ON FRUIT PRODUCTION IN**  
*(Grewia asiatica L.)*

**By**

**SHUBHAM SETH**  
**(J-18-M-551)**

Thesis submitted to Faculty of Postgraduate Studies  
in partial fulfillment of requirements  
for the degree of

**MASTER OF SCIENCE IN AGRICULTURE**  
**ENTOMOLOGY**



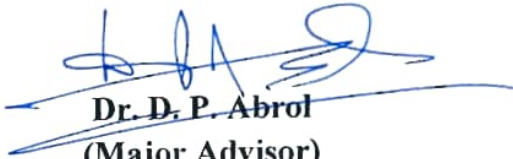
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**Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu**  
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**2021**

## CERTIFICATE-I

This is to certify that the thesis entitled “**Impact of insect pollination on fruit production in *Grewia asiatica* L.**” submitted in partial fulfillment of the requirements for the degree of **Master of Science, in Entomology** to the Faculty of **Post-Graduate Studies** Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, is original work and has similarities with published work not more than minor similarities as per UGC norms of 2018 adopted by the university. Further, the level of minor similarities has been declared after checking the manuscript with **Urkund** software provided by the University.

The work has been carried out by **Mr. Shubham Seth**, Registration No. **J-18-M-551** under my supervision and guidance. No part of the thesis has been submitted for any other degree of diploma. It is further certified that help and assistance received during the course of thesis investigation have been duly acknowledged.



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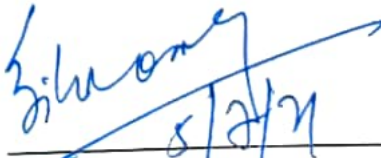
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**Date:** 24-04-2021

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## ABSTRACT

**Title of the thesis** : **Impact of Insect Pollination on Fruit Production in *Grewia asiatica* L.**

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### Abstract

Phalsa is a cross pollinated crop and attracts a large number of insects during its blooming period. Phalsa flowers attracted 15 species of insects belong to 4 orders such as Hymenoptera, Diptera, Lepidoptera and Coleoptera. The insect visitors include 4 species of honey bees such as *Apis mellifera*, *Apis cerana*, *Apis dorsata* and *Apis florea* two species of leaf cutter bees *Megachile bicolor* and *Megachile disjuncta*, one species of *Halictus* bee *Ceratina heiroglyphica* and two species of carpenter bees *Xylocopa fenestrata* and *Xylocopa pubescens*. The other insect visitors were *Eristalis tenax*, *Episyrphus balteatus*, *Metasyrphus corollae*, *Eristalis spp.*, *Papilio demoleus*, *Junomia spp.* and *Coccinella septumpunctata*. Of all these insects, honey bees were the most abundant and important pollinators comprising of more than 75% of the flowers visitors. The other insect visitors such as Leaf cutter bees, *Halictus* bee, Carpenter bees, Syrphid flies, Butterflies and Coccinelids comprised less than 25% of the total insect visitors. Studies on diurnal activity pattern of bees revealed that activity increased with temperature and decreased with relative humidity. The flower visitation rate varied between different bee species and it was highest ( $9.51 \pm 1.48$ ) in *Apis dorsata* and lowest in *Apis florea* ( $2.49 \pm 0.43$ ) flowers per minute. The flower visitation rate of other bee species was in between the two. The study on impact of insect pollination revealed that pollination significantly improved fruit set with 44% in open pollination as compared to 30.6% in self pollination. The fruit weight was significantly higher 0.75g in open pollination and as compared to self pollination 0.57g. The studies clearly demonstrated that insect pollination is essential for quality and quantity of fruit production in phalsa.

  
Signature of Major Advisor

  
Signature of Student

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### INTRODUCTION

Phalsa (*Grewia subinaequalis* Syn. *Grewia asiatica*, family Tiliaceae) is an exotic bush plant considered as a minor fruit crop. It has been included in the State Horticulture programme and is most suited for kandi areas for improving economy and ecology. It is native to the Indian sub-continent and South-East Asia and one of the important fruits of arid and semi arid zones of North India, North western and South Central India. It is cultivated on very small scale in each state. Some of the factors which make this less popular are its small size, long period of ripening, repeated harvesting and perishable nature of fruits. Apart from India it is cultivated in Pakistan, Nepal, Bangladesh, Laos, Sri Lanka, Thailand, Philippines, Vietnam and some provinces of United States of America.

Phalsa bears delicious fruits which contain juice up to 50-60 per cent, sugar 10-11 per cent and acid 2.0 to 2.5 per cent. Ripe phalsa fruits are good source of vitamin 'A' and 'C', phosphorous and iron. According to its nutritional or medicinal value it is beneficial for heart diseases, blood pressure and fever (Gochar *et al.* (2019). It is small bushy and hardy in nature and preferred as an ideal crop for growing in hot and arid regions. It is also preferred for cultivation in dry arid areas. In spite of being very important crop little attention has been paid for its promotion and enhanced cultivation.

The relationship between the flower visitors and host plant, the most critical stages in the reproduction of the plant for the production of quantitatively and qualitatively improved fruits and seeds. Successful pollination is required for quality and quantity of fruit production in phalsa. Pollinators play an important role in quantitative and qualitative characters of variety of fruit crops. Based on the variety and conditions at the site, pollination may increase qualitative and quantitative characters of different fruit crops. Inadequate pollination has been reported to be the reason for low fruit and seed production (Partap, 2001). Insects and bees contribute more than 80% of the total pollination activities and are considered the best pollinators (Robinson and Morse, 1989) and Kumar *et al.* (2020). Insect pollinators are responsible for maintaining the yield and genetic variability in accompanying with sexual reproduction and reducing inbreeding depression in crops. It is therefore important to understand the importance of pollinator's species richness in their natural habitat and role in crop improvement.

*Grewia asiatica* L. (phalsa) (Tiliaceae) is one of the most important fruit plants of great economic importance. Flowering of phalsa starts in February and March continues until May. Many insects are attracted by the abundant pollen and nectar of phalsa flowers. The major pollinators include honeybees (*Apis spp.*) and, to a lesser degree, hoverflies. The important insect pollinators for phalsa are *Apis florea*, *A. mellifera*, *A. dorsata*, *Megachile bicolor* and *Chalicodoma cephalotes* foraging both nectar and pollen. Dey *et al.* (2016) recorded different flower visitors like *Apis dorsata*, *Apis cerena indica*, *Trigona* sp., *Ceratina* sp., *Amegilla* sp., *Megachile* sp., *Halictus* sp., *Xylocopa* sp., *Eumenes* sp, ants, members of Lepidoptera and Diptera on phalsa flowers, Squirrels and Birds have also been recorded visiting phalsa flower for collecting nectar and pollen. In general, honeybees have been reported to be the most important and potential pollinators of phalsa flowers (Free, 1993) and Gill *et al.* (2001) found that fruit set (61.60%) in open pollination was significantly higher than the self-pollination (23.00%). Pollination has been reported to significantly improved the quality and quantity of fruit production. Parmar (1976) reported that in controlled pollination studies on this tropical fruit (Tiliaceae), fruit set was 71.6% in open plots, but only 51.1% on bagged flowers and 81.3%, in hand pollinated flowers. Fruit drop after setting was low. Prajapati *et al.* (2018) recorded the highest foraging rate in *Apis mellifera* (18.25 sec/flower) and least by *Halictus* spp. (7.04 sec/flower) on phalsa flowers. In terms of fruit set under bee pollination (54.0%) was significantly higher than open pollination. Approximately 9-11 kg of phalsa fruit from one tree and average of 4.5-6 ton/ha is produced. Sufficient numbers of pollinators must be during blooming period for sustainable crop production. Proper pollination has been found to increased fruit size, hastens maturity, and produces a more symmetrical fruit shape.

Evidently, successful pollination is required for optimum fruit production which depends upon timely availability of pollinators in sufficient numbers, their foraging behaviour and suitable climatic conditions prevailing during the blooming period.

Keeping in view the above facts, the present study was conducted with the following objectives.

- i. To study the pollinator fauna of Phalsa.
- ii. To study the foraging behavior of different pollinators in relation to weather factors.
- iii. To study the effect of bee pollinators on quantitative and qualitative parameters of Phalsa.

### REVIEW OF LITERATURE

The study was conducted to determine the insect pollinators fauna of Phalsa, foraging behavior and the effect of bee pollinators on quantitative and qualitative parameters. There is scanty literature available and certain aspects are even unknown. The review of literature that follows shall be based on either indirect references or those obliquely connected with the problem. The aim of the review is to prepare ground for confirmation of the same. The information relevant to the problem is reviewed as under following heads:

#### 2.1 Pollinators Fauna in Phalsa

Akram *et al.* (2019) reported that *Grewia asiatica* flowers were visited by *Megachile cephalotes* (Hymenoptera: Megachilidae). They reported that total of 458 individuals belonging to 18 species in three orders visited the flowers of *G. asiatica* i.e. 13 bees (Hymenoptera), 2 butterflies, 1 moth (Lepidoptera) and 2 flies (Diptera). *Megachile cephalotes* comprised 65% of the total floral visitors.

Brunet *et al.* (2019) studied the foraging behaviour of three bee species to pollen dispersal and gene flow. They found that the European honey bee, (*Apis mellifera* L.), the bumble bee, (*Bombus impatiens* Cr.), and the alfalfa leaf cutting bee, (*Megachile rotundata* F.) differed in their foraging behaviour.

Chagnon *et al.* (1989) observed the effect of honey bee visits on the pollination rate of strawberries and found that the number and length of visits to these flowers significantly increased the pollination rate.

Chagnon *et al.* (1991) studied honeybee foraging behaviour and raspberry (*Rubus idaeus* L.) pollination and could find that weight of berries and number of drupelets increased with the number and length of visits.

Chagnon *et al.* (1993) in further studies revealed that the honeybee, *A. mellifera* L. was more efficient than indigenous pollinators when the frequency of visits was very low.

Dey *et al.* (2016) conducted a study on flower visitors of (*Grewia asiatica* L.) and found that different members of Hymenoptera, Lepidoptera, Diptera, Coleoptera (Beetles), Mammals and Birds visited for their forage. Their body parts get dusted with pollen grains and subsequently transferred to the plants resulting in successful pollination. 70% fruits

formation were observed in natural open condition and 20% fruits formation were found in netted condition, but in bagged condition no fruits formation were observed in this plant.

In its natural range, *G. robusta* is believed to be mainly pollinated by nectarivorous birds (Brough 1933; Collins and Rebelo 1987). Brough (1933) found that bees were abundant on inflorescences of *G. robusta* in Sydney, Australia, and less attracted at Malava. Nicolson (1993) reported that at Cape Town, South Africa, honeybees did not visit *G. robusta* flowers (Nicolson 1993).

Kitroo and Abrol (1996) conducted studies on abundance, diversity and importance of native pollinators for fruit production in litchi (*Litchi chinensis* Sonn.), and found that honeybees *Apis dorsata* F., *A. mellifera* L., *A. cerana* F., and *Apis florea* F. were the most important and efficient pollinators. According to them insect pollination was responsible for the increase in fruit production and fruits resulting from open pollination were significantly higher in size and weight.

Klug and Buenemann (1985) compared the efficiency of solitary bees and honeybees as pollinators of pome fruits. They found that the number of solitary bees was very small in comparison to the number of honeybees. Solitary bees visited fewer flowers per minute than honeybees. However, in most cases they touched the stigmas compared to honeybees.

Kumar (2010) reported that *Halictus* sp. as most abundant visitor among three bee species. Similarly *Trigona* spp., *Halictus* sp. and lepidopterans were the most frequent visitors among the different insect pollinators.

Kumar *et al.* (2016) found that in numerous insects of the orders Hymenoptera, Diptera, Lepidoptera and Coleoptera visited mango flowers. Among Hymenopterans insects, different species of honey bee were most abundant.

Kumar *et al.* (2020) conducted a study on Wild bee pollination in *Grewia flavescens* Juss and recorded a total of 25 species of floral visitors. The most abundant floral visitors belong to the family Megachilidae (48.35%) followed by Apidae (27.21%), Halictidae (10.29%) and others (14.15%). Non-*Apis* species exhibited significantly greater abundance and constituted 83% of the total floral visitors as compared to 17% of *Apis* visitors. Among the non-*Apis* group, Megachilidae constituted 75.01% compared to Apidae (19.11%) and Halictidae (5.88%). Wasps, flies, moths and butterflies were excluded since their abundance was very low.

Mahfouz *et al.* (2019) reported that insect pollinators visiting sesame flowers belonged to Hymenoptera, Coleoptera, Lepidoptera and Diptera. Among the bees, *Apis mellifera* was most abundant followed by *Xylocopa* sp. and lastly *Anthidium* sp. they also found that temperature, wind and relative humidity affected the percentage of insects visiting sesame flowers.

Most of the studies conducted in South Africa on *G. robusta* flowers revealed that sunbirds were the most frequent visitors (Collins and Rebelo 1987; Nicolson 1993 Kalinganire *et al.* (1996). Kalinganire *et al.* (2001) found that the floral visitors of silky oak, *Grevillea robusta* studied at Malava, western Kenya were birds and insects. They included sunbirds (*Nectarinia amethystina*, *N. cyanolaema*, *N. olivacea*, *N. superba* and *N. venusta*). They did not find nocturnal pollinators. They further found that hundreds of ants visited flowers at all times throughout the day for nectar whereas honeybees rarely visited the flowers.

Rakesh *et al.* (2019) recorded 13 species of insects belonging to order Hymenoptera Diptera and Coleoptera. Hymenopterans were most abundant followed by (77.71%) by Dipterans (22.27%). Among Hymenopterans, *A. dorsata* (50.11%) was predominant visitor followed by *A. cerana* and *A. indica* (11.80%), *A. florea* (8.68%) and *A. mellifera* (7.12%).

Singh (1984) conducted studies on the activity of some insect pollinators on jujube (*Zizyphus mauritiana* Lamk.) and found that honeybees were the more efficient pollinators while frequency of visits of houseflies to receptive flowers was more.

Thapa (2006) conducted a study on honeybees and other insect pollinators of cultivated plants. He found that of the total pollination activities, over 80% are performed by insects and bees contribute nearly 80% of the total insect pollination.

Udikeri and Chandra (2019) recorded a total of nineteen different insect species were visiting the Phalsa flowers which included insects belonging to Megachilidae, Vespidae, Apidae, Halictidae, Xylocopidae, sarcophagidae, Calliphoridae and Syrphidae, Pieridae, Nymphalidae and Amatidae.

Vaissiere *et al.* (1996) determined the pollination effectiveness of honeybees in a kiwifruit (*Actinidia chinensis*) orchard and concluded that honeybees are effective pollinators of kiwifruit.

## 2.2 Foraging behavior of different pollinators

Akram *et al.* (2019) conducted a study on difference in foraging behavior of male and female *Megachile cephalotes* Smith (Megachilidae) and reported that there was no significant difference between male and female *M. cephalotes* in terms of stay time. However, visitation frequency, visitation rate and pollen deposition of females were significantly higher than that of males.

Cavalcante *et al.* (2012) found that Brazil Nut (*Bertholletia excelsa* Bonpl.) attracted nineteen bee species, belonging to two families, visited and collected nectar and/or pollen throughout the day.

Clarke and Robert (2018) foraging activity of honey bees (*Apis mellifera*) variation in bee activity was explained by variation in temperature and solar radiation.

Dashad and Sharma (1994) found that pollen gatherers had higher foraging rate as compared to nectar and nectar-pollen foragers among *Apis* spp. on various cultivars of apple (*Malus domestica* Borkh). All three kinds of foragers of *Apis dorsata* had higher foraging rates as compared to their counterparts of *A. cerana* and *A. mellifera*. Dipteran flies had very low foraging rate as compared to honeybees.

Dashad *et al.* (1994) found that carrying capacity of loose pollen grains by different insect-visitors of apple bloom varies with the plant species and the varieties on which the insects are working.

Dominic *et al.* (2018) studied the Predictive modeling of honey bee foraging activity using local weather conditions and investigated the connection between foraging activity of honey bees (*Apis mellifera*) and local weather conditions. They found that 78% of the observed variation in bee activity was explained by variation in temperature and solar radiation.

Eeraerts *et al.* (2019) studied the Pollination efficiency and foraging behaviour of honey bees and non-*Apis* bees to sweet cherry. The studies revealed that solitary bees and especially mason bees were most efficient pollinators as compared with bumble bees and honey bees.

Further studies on pollination of guava (*P. guajava* Linn.) by honey bees (*A. cerana*, *A. indica* and *A. florea*) by Jyothi (2004) at East Godavari district of Andhra Pradesh came to a conclusion that fruit set was increased by honey bee pollination.

Further studies on the behaviour of *A. cerana* and *A. mellifera* foraging on apple flowers by Verma and Rana (1994) showed that *A. mellifera* visited significantly more flowers than *A. cerana* during single 15 foraging trips at each site. However, number of flowers visited per minute did not vary between two species.

Gupta *et al.* (1990) studied the pattern of nectar secretion in wild cherry, *Prunus puddum Roxb.* and the associated foraging behaviour of *Apis cerana*, *A. indica*, *A. florea* and *A. mellifera L.* According to them honey bees foraged both for nectar and pollen on the flowers. The pollen gathering activity of was maximum during morning hours (8-9 hrs.) and nectar gathering peaked at hours. *A. mellifera* spent more time per flower than *Apis cerana* and *A. indica*, whether foraging for nectar or pollen.

Heard (1994) studied the behavior and pollinator efficiency of stingless bees (*Trigona carbonaria*) and honeybee (*A. mellifera*) on macadamia flowers. Stingless proved better pollinators as they mainly collected pollen. Honeybees mainly collected nectar and came into contact with the stigma less often. Racemes pollinated by smaller stingless bees yielded fruit set equal to that on open pollinated racemes, indicating them as efficient pollinators. Honeybees worked more quickly than the stingless bees, visiting more flowers in a given time. Both bee species responded to racemes rich in pollen and nectar by remaining longer at those racemes and visiting more flowers on them.

Ish-Am and Eisikowitch (1998) studied the mobility of honey bees (*A. mellifera L.*) during foraging avocado orchards and found that the 16 average number of bees crossing between adjacent rows in a 10 min. period was linearly correlated to bee density, and the corresponding percentage increased with the increase in wind velocity, and decreased with increasing distance from the pollen source. The guava (*Psidium guajava L.*) flowers were visited by four insect species viz. *A. cerana*, *A. indica*, *A. florea*, *Melipona fasciata* and *Musca domestica*. The relative abundance, pollen depletion, pollen deposition and time spent at flowers revealed that the honeybees, *A. cerana*, *A. indica* and *A. florea* were the major pollinators of guava. The diurnal activity of pollinators showed a significant negative correlation with humidity. The amount of pollen deposited by the pollinators during the successive visits was found to decrease because of the decreasing stigma receptivity with time. The amount of pollen deposited was found to be more at 0800 h due to more pollen stickiness and stigma receptivity (Prakash *et al.*1993).

Joshi and Joshi (2010) studied the foraging behavior of *Apis* Spp. and found that pollen loads carried by *A. mellifera* were heavier than *A. cerana*. The foraging activity of *A. cerana* was observed at a peak between 1100 to 1300 hrs and declined thereafter. Activity of *A. mellifera*, reached its peak between 1300 to 1500 hrs.

kumar *et al.* (2020) recorded 25 species of floral visitors on *G.asiatica* and found that Megachilidae was the most abundant followed by Apidae, Halictidae and others. They further found that megachile and xylocopa were more effective in depositing pollen.

Kumar *et al.* (2020) studied the foraging behaviour of three Megachilidae, Apidae and Halictidae. The activity of Megachilidae started between 08.00–09.00 h and peak foraging activity was recorded between 11.00–13.00 h. whereas, the peak foraging activity of Apidae was around 12.00–13.00 h (except) *A. florea* which started between 10.00–11.00 h and its maximum abundant was between 14:00–17:00 h).

Marcia *et al.* (2017) conducted a study on foraging of honeybees on flowers of yellow mellon. They compared bee visitation to hermaphrodite (HF) and male (MF) flowers in a crop area where different number of hives were used. They found that HF received significantly longer visits than MF, in all experiments, except when using one hive.

Prajapat *et al.* (2018) found that temperature prevailing during early hours of the day was most favorable for pollinator activity. *Apis mellifera* exhibited highest foraging rate as compared to by *Halictus* spp. fruit set under bee pollination (54.0%) was significantly higher than open pollination (41.8%) and self pollination (28.0%).

Rakesh *et al.* (2019) conducted a study on insect pollinators with special reference to foraging behavior of honey bees to record the different insect pollinators with special reference to foraging behavior of honey bees visiting flowers. The found that foraging speed was maximum in *A. dorsata* and minnum in *A. florea* .

Tura Bareke *et al.* (2019) studied the Effect of honeybee pollination on seed and fruit yield of agricultural crops in Ethiopia. They found that Studies honeybee pollination resulted in improving the yield and quality of some crops such as *Malus sylvestris* (apple), *Allium cepa* (red onion), *Guizotia abyssinica* (niger) and *Vicia faba* (faba bean). The yield increment was varied from 33.5-84% among the above crops due to honeybee pollination. Studies on pollen sources for *Apis cerana* *Apis floreae* and *Apis mellifera* bees by Suryanarayana *et al.* (1992) at Muzaffarpur, Bihar, India showed that each of the species had 13 anemophilous

plant species as sources of pollen. Studies on the pollinator activities on mango inflorescence indicated that *Apis florea* was the most frequent visitor followed by *Syrphid spp.*, *Ceratina viridissima*, *X. pubescens*, *Xylocopa fenestrata* and *Megachile aurigata*. The activity of *Nomia thoracica*, *Tachina spp.* and *Musca spp.* was almost negligible.

Udikeri and Chandra (2019) studied the Pollination efficiency of different insects on Phalsa *Grewia subinaequalis* D.C. They found *Apis dorsata* to visit more number of flowers in a minute by spending very less time per flower. *A. mellifera*, *Halictus sp.*, *Polistes olivaceus* and *Megachile sp.* found visiting 9.35, 6.27, 4.16 and 3.92 number of flowers in a minute and spent 2.82, 6.55, 7.89, 7.31 seconds on flower respectively. Highest fruit setting (59.17%) was recorded in the bee pollinated plants followed by open pollinated plants under Kumarganj agro-ecological conditions.

Verma and Dulta (1986) studied foraging behaviour of *Apis cerana*, *A. indica* and *A. mellifera* in pollinating apple flowers. *A. c. indica* started foraging early in the morning than *A. mellifera* and continued up to late hours in the evening as compared to *A. mellifera*. In both species nectar collectors out numbered pollen collectors. Peak foraging activity for *A. cerana*, *A. indica* occurred at 0900 h. -1130 h. when the temperature ranged between 15.5 and 21°C and 1100 h -1330 h. for *A. mellifera* when the temperature was 21 to 25°C.

Verma *et al.* (1994) studied the Foraging behaviour of *Apis cerana* and reported that bees started foraging on plants at 07.00 h and 06.30 h, respectively, and ceased flight activity at 18.00 h and 18.30 h, respectively. Foraging started at ambient temperatures of 7°C.

### **2.3 Effect of bee pollination on qualitative and quantitative parameters.**

Abrol (1989) found that in insect pollination of cherry (*Prunus avium L.*), flowers covered with muslin cloth did not set any fruit while those left for open pollination set 38-56% fruits.

Abrol *et al.* (2017) studied the Impact of insect pollinators on yield and fruit quality of strawberry the Investigations were conducted to determine the insect pollinators visiting strawberry blossoms and their impact on fruit production. They found that percentage of fruit set was much higher in open pollinated plants than control. Malformed fruits in open pollinated were significantly less as compared to controlled one.

Akram *et al.* (2019) conducted a study on difference in foraging behavior of male and female *Megachile cephalotes* Smith (Megachilidae) and reported that open, female and male pollinated fruits were different in terms of their weight (d.  $f=2$ ,  $f=8.84$ ,  $p=0.001$ ). The maximum average weight was recorded for female *M. cephalotes* pollinated fruits followed by open and male pollinated fruits which were also non-significant.

Antonelli *et al.* (1988) conducted studies on pollinating insects and strawberry yields in the Pacific Northwest and found that “Benton” and “Shuksan” strawberry plants denied insect pollinators during bloom produced significantly fewer berries and berry quality was significantly reduced.

Aras *et al.* (1996) noted the effect of honeybee gradient on the pollination and yield of low bush blue berry. All parameters were significantly and positively correlated with an increase in the density of honeybees.

Bagnara and Vincent (1988) studied the role of insect pollination and plant genotype in strawberry fruit set and fertility. Open pollination, compared to absence of insects under cages decreased the percentage of poorly pollinated fruit and increased the number of fruit set.

Bhattacharya (2004) conducted a study on pollination of *Anacardium occidentale* and found that bees, flies, butterflies, beetles and ants were the visitors of the flowers. Relative abundance of the visitors coincided with nectar availability. Breeding manipulation by bagging experiments indicated that bees were efficient pollinators increasing fruit set, while ants decreased fruit set by damaging the viable pollen.

Dedig and Delaplane (2003) studied honey bee pollination of rabbitey blue berry, *Vaccinium ashei* variety “climax” and found that the pollination was pollinator density dependant. Regression analysis showed that fruit set increased linearly with the rate of legitimate bee visits. Average seeds per berry tended to increasing bee density.

Dey *et al.* (2016) conducted a study on visitor interaction and fruit production of (*Grewia asiatica* L.). 70% fruits formation was observed in natural open condition and 20% fruits in netted condition, but in bagged condition no fruits formation was observed in this plant.

Gill *et al.* (2001) conducted a study on effect of modes of pollination on fruit set and insect pollinators of phalsa (*Grewia subinaequalis* D. C.). They found that fruit set (61.60%) in open pollination was significantly higher than the self-pollination (23.00%). The main insect pollinators for phalsa are *Apis florea*, *A. mellifera*, *A. dorsata*, *Megachile bicolor* and *Chalicodoma cephalotes* were observed foraging both nectar and pollen, while other foraged for nectar only.

Gingras *et al.* (1999) reported that in Cucumber (*C. sativus* L.) flowers that had the greatest number of visits had the greatest cucumber yields. No significant relation was found between cucumber weight and the number of cumulative duration of visits by bees. The presence of honeybees together with the number and cumulative duration of their visits 39 to the flowers are important to pollination and influence both the quality and quantity of cucumber production.

Harrap *et al.* (2017) reported that pollinating insects utilise various sensory cues such as floral temperature that assist pollinators in the recognition and learning of rewarding flowers.

Honey bee pollination can increase production depending upon the location and prevailing conditions. It is therefore necessary to understand the importance of pollinator's species richness in their natural habitat and role in crop improvement (Pashte *et al.* 2015).

Hosamani *et al.* (2020) reported that in Onion (*Allium cepa*) Seed the open pollinated plot sprayed with cacambe were significantly superior over open pollination without spray and caged plot without bees, respectively.

Howpage *et al.* (2001) studied influence of honeybee (*A. mellifera*) on kiwifruit quality under Australian conditions and found that there were significantly more small fruit in bee saturated vines than in vines that were supplementary pollinated by honeybees. According to them honeybees were the main contributor to pollination and fruit set, although low numbers of other potential insect pollinators such as ladybird beetles and hoverflies were also observed.

Jones *et al.* (1976) obtained an abnormally high incidence of honey bee visitation to flowers of Chinese gooseberry (*Actinidia chinensis*) in New Zealand. The weight of fruit

formed in the cages was not significantly different from that in the surrounding crop, but caged fruits had fewer seeds.

Kumar *et al.* (2020) conducted a study on Wild bee pollination in *Grewia flavescens* Juss and recorded the fruit-set among the different pollination treatments indicated that Megachile and Xylocopa species are effective in cross pollination and fruit set (26.67–41.11% and 56.67%, respectively).

kumar *et al.* (2020) found that fruit set in different treatments was 71.42% in open pollination, 68.33 % in artificial cross pollination and 22.22 % in self pollination.

Langridge *et al.* (1977) conducted a study on pollination of dessert peaches by *A. mellifera* and found that in trees to which bees had access there was a 2.9x increase in percentage of flowers that set fruit and a 2.6x increase in weight of fruit.

Manzoorul-Haq *et al.* (1978) found that insect pollination resulted in significantly more fruit set and matured fruits on branches accessible to insect pollinators in kinnow mandarin (*citrus reticulata*).

Neira *et al.* (1997) observed the entomofauna associated with flowers of raspberry (*Rubus idaeus* L. cv Meeker). The results show that the presence of pollinating insects was essential for fruit formation and to decrease floral abortion and abnormal fruits.

Parmar (1976) while studying the pollination and fruit set in phalsa (*Grewia asiatica* L.) reported that in controlled pollination, fruit set was 71.6% in open plots, but only 51.1% on bagged flowers. Hand crossing resulted in a fruit set of 81.3%, indicating that the amount of cross-pollination in open plots could be increased. The major pollinators were honeybees (*Apis spp.*) and, to a lesser degree, hoverflies. Fruit drop, after setting, was low.

Pomeroy and Fisher (2002) also studied pollination of kiwifruit by bumble bees (*Bombus terrestris*). They also found that fruit weight and seed number in the cages increased with increasing bee density.

The entomophily of the cloudberry (*Rubus chamaemorus* L.) was studied by Pelletier *et al.* (2001). According to them the activity of natural pollinators resulted in good fruit set and seed set, fruit set dropped significantly when insects were excluded. Natural levels of insect activity were sufficient to ensure complete pollination as supplementary hand-

pollination did not significantly increase either fruit set or seed set in plots where pollinators had free access. Nocturnal insects may serve as pollinators although they were less effective than diurnal pollinators

Walters and Stiles (1996) studied flower patch size on pollinator visitation of *Impatiens capensis* and found that honeybees, bumblebees and halictid bees made up the majority of visitors. Visitation rates per flower increased slightly in relation to flower patch size and floral density.

## CHAPTER-III

### MATERIALS AND METHODS

The field studies to determine the impact of insect pollination on fruit production in *Grewia asiatica L.* were conducted at Regional Horticultural Research Sub-Station (RHRSS), of Sher-e-Kashmir university of Agricultural Sciences and Technology Jammu located at Raya Samba District (Jammu and Kashmir) during the period 2019-20.

#### 3.1 Experimental site

The experimental site is located in the sub-tropical zone at 32.73°N and longitude of 74.87°E. It has an average elevation of 327m from the mean sea level. Most of the rains are received during July to October (about 70 percent). The annual mean maximum and minimum temperature are 29.60 and 16.70°C, respectively. Summer months are hot with temperature and humidity ranging from 23.50 to 35.50°C and 53.0 to 73.50 percent, respectively. The winter months experience mild to severe cold conditions with average temperature ranging from 6.50 to 21.70°C. December is the coldest month, when minimum temperature touches 4°C. The highest temperature is recorded in the month of June (4 °C). The daily maximum and minimum temperature and evaporation rate rise from March onwards. The detailed material and methods employed for these studies are reported in this chapter objective wise.

#### 3.2 Details of experiments

The experiment was carried out in Randomized Block Design (RBD). The experiment consisted of five treatments which were replicated five times.

#### 3.3 Diversity of pollinator fauna

The entomofauna visiting blooming phalsa was collected by sweep net method. The collected insects were sundried or preserved in 70% alcohol for further identification. The collected insects were identified with the help of taxonomic keys and later confirmed by the taxonomists.

### **3.4 Foraging behavior of the pollinators**

Each of insect species was observed for its foraging behaviour in terms of collection of nectar/pollens. Foraging activity, i.e., initiation, peak activity and cessation time of different bee species were visually recorded. The activity of insect visitors on phalsa flowers was recorded from 9:00am to 16:00 hours at 2 hourly intervals at the beginning of each hour. For this purpose 5 branches of phalsa plants were marked and the number of bees visiting each branch recorded for 5 minutes. The average number of bees visiting each hour were calculated accordingly.

### **3.5 Foraging rate**

Foraging rate of bees were recorded in terms of time (second) spent by them on each flower and the number of flowers visited per minute following the method given by Free (1993). The bee visiting a each flowers were recorded with a chronometer with an accuracy 0.01 second. The number of flower visited were recorded and calculated bee per unit time. The value of flowers visited per minute were calculated accordingly.

### **3.6 Pollination efficiency**

Comparative pollination efficiency of different bee species were assessed based on their relative abundance and foraging behavior on phalsa flowers Similarly in open pollination the percentage of fruit set was recorded to determine the percent fruit set.

### **3.7 Effect of modes of pollination**

Effect of pollination such as self-pollination (Without insect pollination), open pollination on fruit set were determined. In self pollination the five flowering branches were bagged with muslin cloth and were deprived of bee visits. In open pollination, five branches were left for open pollination. The bags were removed after fruit set. Total number of flowers on the branches were counted and fruit formed from the pre-counted flowers were recorded after one month of flowering to determine the per cent fruit set. Similarly in open pollination the percentage of fruit set was recorded to determine the percent fruit set.

The impact of pollination was calculated by determining the fruit weight and fruit volume in open pollination and self pollination and compared accordingly.

The collected data were analysis for correlation with weather parameters and for differences of fruit set using spectacles method as suggested by Hogg *et al* (2019).

**RESULTS**

The studies were conducted to determine the insect pollinators visiting phalsa flowers, their foraging behaviour in relation to weather parameters and impact of insect pollination on qualitative and quantitative parameters of phalsa. The results obtained are presented under the following heads:

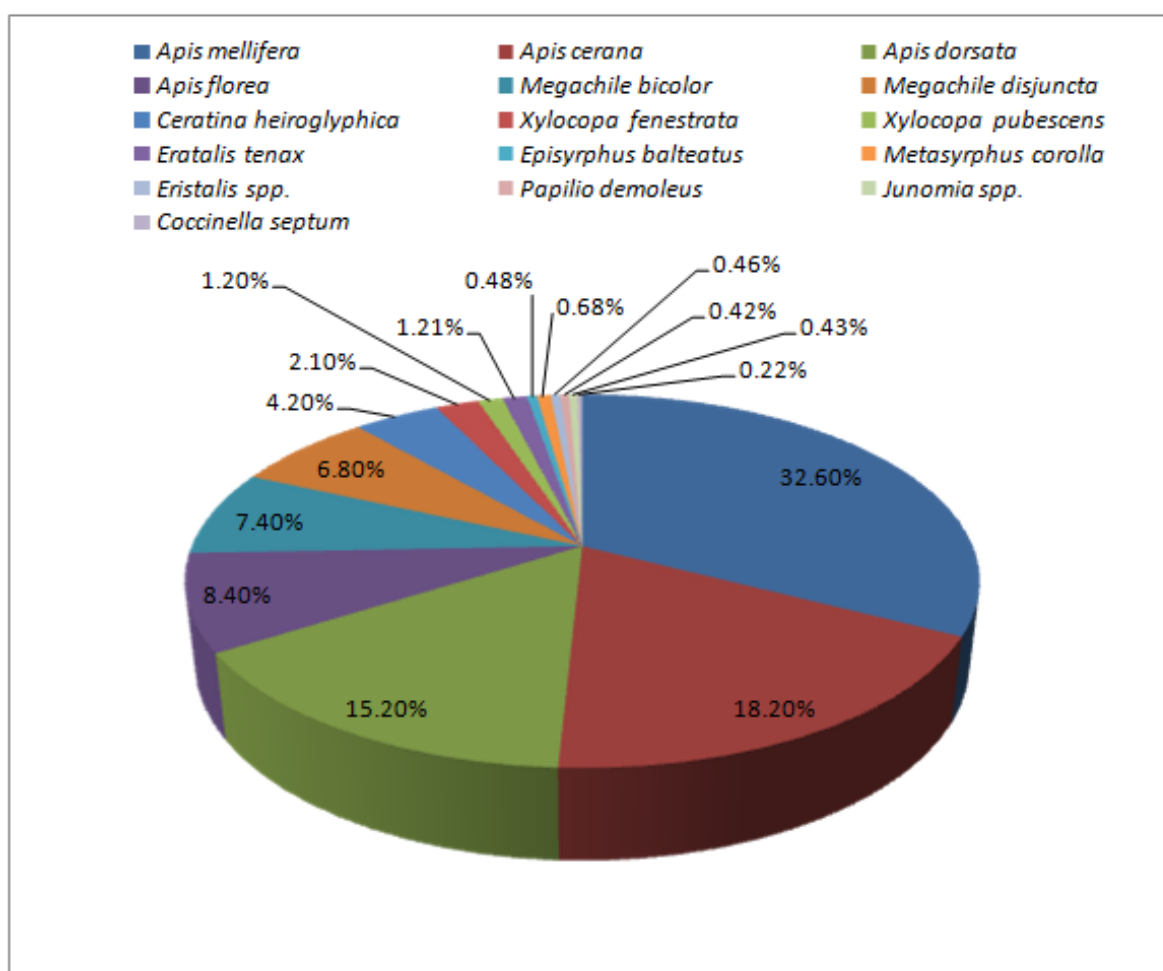
**4.1 Insect visitors on phalsa flower and their species composition**

Phalsa is a cross pollinated crop which attracts more number of pollinators during the blooming period. Insect visitors collected from Phalsa flowers has been listed in Table 1. Phalsa flowers attracted insects belonging to four orders which included Hymenoptera, Diptera, Lepidoptera and Coleoptera. Of all the orders, insects belonging to order Hymenoptera were most abundant. They included honey bee *Apis mellifera*, *Apis cerana*, *Apis dorsata*, and *Apis florea*. Honeybee in general comprised of more than 75% of the total flower visitors. The phalsa flowers were also visited by solitary bees such as Leaf cutter bees *Megachile bicolor* and *Megachile disjuncta* which were more than 14% of the total flower visitors. The other flower visitors included Halictid bee such as *Ceratina hieroglyphica* and Carpenter bee such as *Xylocopa fenestrata*, *Xylocopa pubescens* and other species such as *Eristalis tenax*, *Episyrrhus balteatus*, *Metasyrrhus corolla*, *Eristalis spp.*, *Papilio demoleus*, *Junomia spp.*, *Coccinella septumpunctata*. The other flower visitors were few in numbers as compared to honey bee and solitary bees.

The data presented in Figure 1 showed the percentage composition in different insects on phalsa flowers. The data showed that honey bee were most abundant flowers visitors and comprised above 75% of flowers visitors followed by leaf cutter bees, Halictid bee, carpenter bees and other flower visitors which comprised less than 25% of the total insect visitors. The overall abundance of insects visitors was in the order: *Apis mellifera* > *Apis cerana* > *Apis dorsata* > *Apis florea* > *Megachile bicolor* > *Megachile disjuncta* > *Ceratina hieroglyphica* > *Xylocopa fenestrata* > *Xylocopa pubescens*. The data clearly shows that the honey was most reliable flowers visitors were as the other bee pollinators were observed in few number at interrupted hours.

**Table 1. List of insect visitors on phalsa flowers at Raya Farm, Jammu during 2020**

<b>Order</b>	<b>Common Name</b>	<b>Scientific Name</b>	<b>Family</b>	<b>Percentage composition</b>
Hymenoptera	Italian bee	<i>Apis mellifera</i>	Apidae	32.60
	Indian bee	<i>Apis cerana</i>	Apidae	18.20
	Giant bee	<i>Apis dorsata</i>	Apidae	15.20
	Little bee	<i>Apis florea</i>	Apidae	8.40
	Leaf cutter bee	<i>Megachile bicolor</i>	Megachilidae	7.40
		<i>Megachile disjuncta</i>	Megachilidae	6.80
	Halictid bee	<i>Ceratina heiroglyphica</i>	Halictidae	4.20
	Carpenter bee	<i>Xylocopa fenestrata</i>	Xylocopinae	2.10
<i>Xylocopa pubescens</i>		Xylocopinae	1.20	
Diptera	Syrphid flies	<i>Eratalis tenax</i>	Syrphidae	1.21
		<i>Episyrphus balteatus</i>	Syrphidae	0.48
		<i>Metasyrphus corollae</i>	Syrphidae	0.68
		<i>Eristalis spp.</i>	Syrphidae	0.46
Lepidoptera	Butterflies	<i>Papilio demoleus</i>	Papilionidae	0.42
		<i>Junomia spp.</i>	Lycaenidae	0.43
Coleoptera	Ladybird beetle	<i>Coccinella septumpunctata</i>	Coccinellidae	0.22



**Fig. 1. Percentage composition of different insect visitors on Phalsa flowers at Raya Farm, Jammu during 2020**

#### 4.2 Diurnal pattern of insect visitors on phalsa flowers

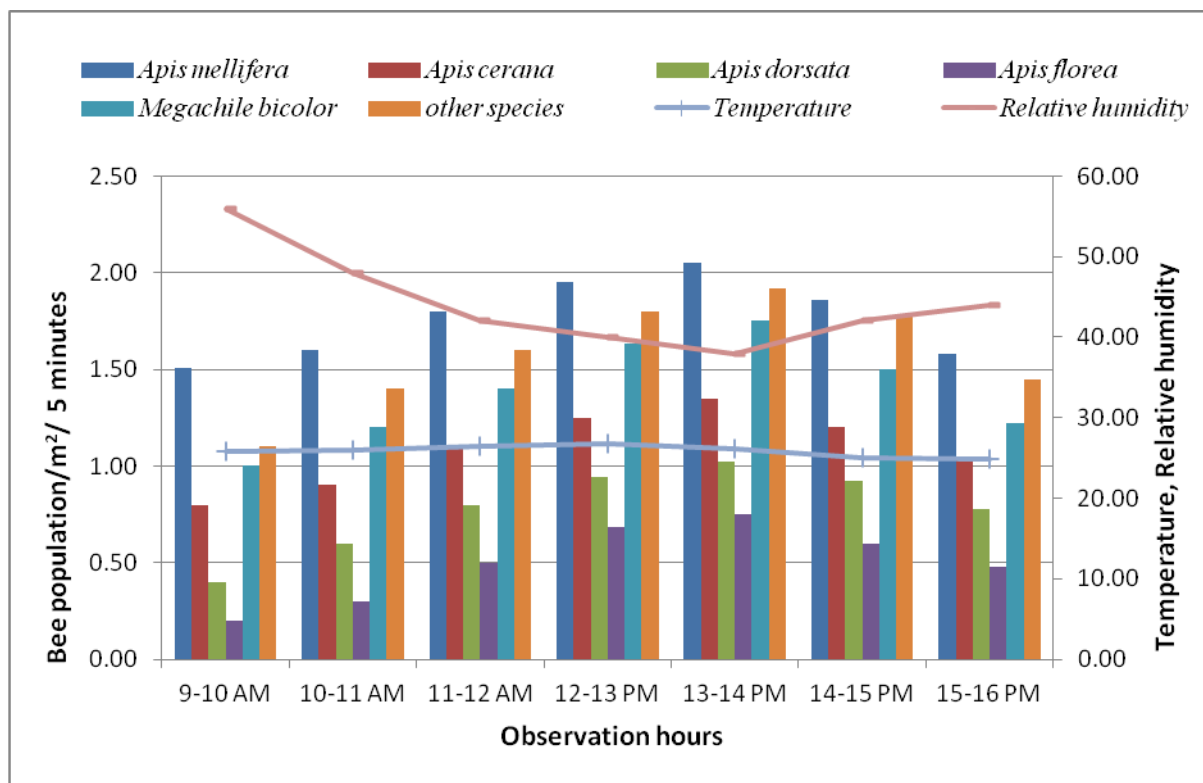
The studies were conducted at weekly intervals on phalsa flowers with effect of 18<sup>th</sup> March to 23<sup>rd</sup> April 2020 in relation with abiotic factors. The data collected on 18<sup>th</sup> March 2020 presented in Table 2 Fig. 2 shows that *Apis mellifera*, *Apis cerana*, *Apis dorsata*, *Apis florea*, *Megachile bicolor* and other species visited the phalsa flowers. *Apis mellifera* was most abundance followed by *Apis cerana*, *Apis dorsata*, *Apis florea*, *Megachile bicolor* and other species. The population of all the honey bee species was low in the morning hours i.e, 09:00 to 10:00am which increase 10 am onwards and reached peak between 13:00 to 14:00 hours. The population declined there after and were low between 15:00 to 16:00 hours. The data presented in Fig. 2 clearly showed that increase in population followed the same general pattern as increase in temperature, however, reverse trend was observed with increase in relative humidity.

Correlation analysis of the data presented in Table 2 showed that populations dynamics of *Apis mellifera*, *Apis cerana*, *Apis dorsata*, *Apis florea*, *Megachile bicolor* were significantly correlated with increasing temperature. However, relationship of *Apis florea* and other species with temperature was found to be non-significant. This may be due to the reason that there population was low in numbers and observed at interrupted hours.

The data presented in Table 3 further showed that there was significant negative correlations with relative humidity in all the bee species there by indicating that the bees followed as inverse relationship with relative humidity.

**Table 2. Diurnal pattern of insect pollinators on phalsa flowers in relation to abiotic factors on 18 March 2020**

Observation (h)	Number of bees/5 branches/5min						Temperature (°C)	Relative humidity (%)
	<i>A.mellifera</i>	<i>A.cerana</i>	<i>A.dorsata</i>	<i>A.florea</i>	<i>M. bicolor</i>	Others		
0900-1000	1.51 ± 0.28	0.80 ± 0.20	0.40 ± 0.02	0.20 ± 0.1	1.00 ± 0.02	1.10 ± 0.20	25.80	56.00
1000-1100	1.60 ± 0.21	0.90 ± 0.18	0.60 ± 0.04	0.30 ± 0.02	1.20 ± 1.12	1.40 ± 0.22	26.00	48.00
1100-1200	1.80 ± 0.48	1.10 ± 0.25	0.80 ± 0.10	0.50 ± 0.11	1.40 ± 0.18	1.60 ± 0.32	26.40	42.00
1200-1300	1.95 ± 0.72	1.25 ± 0.27	0.94 ± 0.14	0.68 ± 0.12	1.63 ± 0.28	1.80 ± 0.47	26.80	40.00
1300-1400	2.05 ± 0.48	1.35 ± 0.28	1.02 ± 0.12	0.75 ± 0.20	1.75 ± 0.37	1.92 ± 0.44	26.20	38.00
1400-1500	1.86 ± 0.28	1.20 ± 0.17	0.92 ± 0.10	0.60 ± 0.14	1.50 ± 0.48	1.77 ± 0.20	25.00	42.00
1500-1600	1.58 ± 0.48	1.05 ± 0.21	0.78 ± 0.20	0.48 ± 0.08	1.22 ± 0.27	1.45 ± 0.24	24.90	44.00
Mean ± S.D	1.76 ± 0.41	1.09 ± 0.22	0.78 ± 0.08	0.50 ± 0.11	1.39 ± 0.38	1.58 ± 0.29	25.87	44.28



**Fig. 2. Diurnal pattern of insect pollinators on phalsa flowers in relation to abiotic factors on 18 March 2020**

**Table 3. Correlation between bee visitation on phalsa flowers with abiotic factors on 18 March 2020**

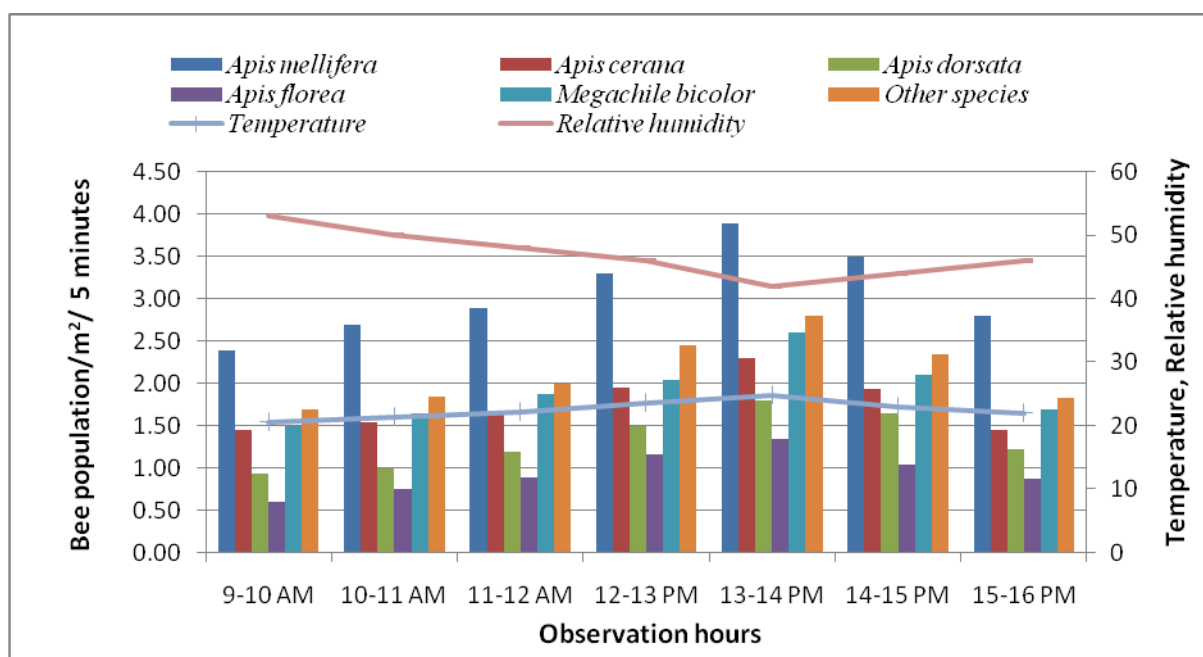
Bee species	Temperature (°C)	Relative humidity (%)
<i>Apis mellifera</i>	0.354*	-0.947**
<i>Apis cerana</i>	0.436*	-0.864**
<i>Apis dorsata</i>	0.349*	-0.980**
<i>Apis floreae</i>	0.212*	-0.950**
<i>Megachile bicolor</i>	0.377*	-0.920**
Other species	0.250*	-0.956**

\*Correlation is significant at 0.05 level (2 tailed)

\*\* Correlation is significant at 0.01 level (2 tailed)

### 4.3 Diurnal pattern of bee activity on phalsa flowers on 25-03-2020

The data presented in Table 4 fig. 3 revealed that the same species of bee visited phalsa flowers on 25-03-2020 as observed on 18<sup>th</sup> March 2020. However, the populations of each bee species was significantly more than those observed on 18-03-2020. The diurnal trend of bees followed the same pattern as observed on 18-03-2020 with peak between 13:00 to 14:00 hours. The number of bee visits increased with increase in temperature. However there was decrease in number of bees with increase in humidity. The data in Table 5 on correlation analysis revealed that there was highly significant positive correlations with temperature in all the bee species and highly significant negative correlation with relative humidity.



**Fig. 3. Diurnal pattern of insect pollinators on phalsa flowers in relation to abiotic factors on 25 March 2020**

**Table 4. Diurnal pattern of insect pollinators on phalsa flowers in relation to abiotic factors on 25<sup>th</sup> March 2020**

Observation (h)	Number of bees/5 branches/5min						Temperature (°C)	Relative humidity (%)
	<i>A.mellifera</i>	<i>A.cerana</i>	<i>A.dorsata</i>	<i>A.florea</i>	<i>M. bicolor</i>	Others		
0900-1000	2.40 ± 0.48	1.45 ± 0.42	0.95 ± 0.10	0.60 ± 0.10	1.50 ± 0.28	1.70 ± 0.28	20.6	53
1000-1100	2.70 ± 0.52	1.55 ± 0.28	1.00 ± 0.02	0.75 ± 0.12	1.65 ± 0.48	1.85 ± 0.32	21.4	50
1100-1200	2.90 ± 0.62	1.65 ± 0.42	1.20 ± 0.12	0.90 ± 0.14	1.88 ± 0.28	2.00 ± 0.42	22.2	48
1200-1300	3.30 ± 0.72	1.95 ± 0.44	1.51 ± 0.28	1.16 ± 0.18	2.04 ± 0.52	2.45 ± 0.52	23.6	46
1300-1400	3.90 ± 0.48	2.30 ± 0.48	1.80 ± 0.22	1.35 ± 0.32	2.60 ± 0.42	2.80 ± 0.51	24.8	42
1400-1500	3.50 ± 0.44	1.94 ± 0.28	1.65 ± 0.24	1.05 ± 0.14	2.10 ± 0.42	2.35 ± 0.48	23	44
1500-1600	2.80 ± 0.32	1.45 ± 0.22	1.23 ± 0.17	0.88 ± 0.18	1.70 ± 0.32	1.83 ± 0.42	22	46
Mean ± S.D	3.07 ± 0.51	1.76 ± 0.36	1.33 ± 0.16	0.96 ± 0.16	1.92 ± 0.38	2.14 ± 0.42	22.51	47

**Table 5. Correlation between bee visitation on phalsa flowers with abiotic factors on 25 March 2020**

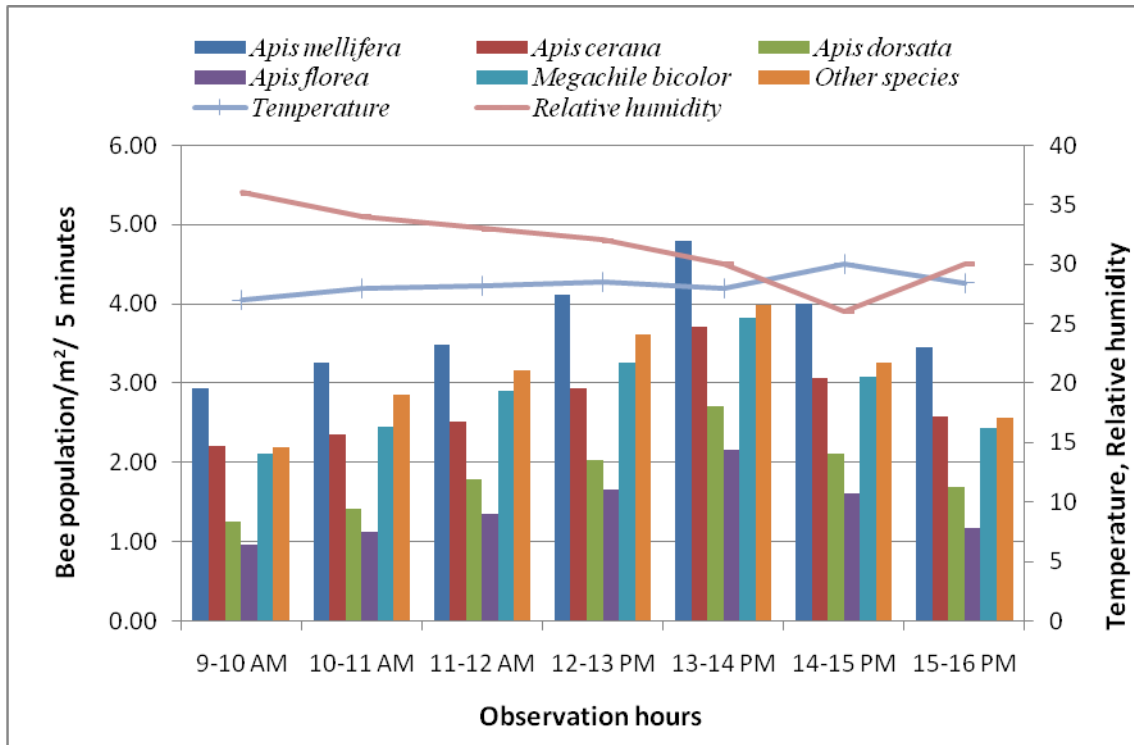
<b>Bee species</b>	<b>Temperature (°C)</b>	<b>Relative humidity (%)</b>
<i>Apis mellifera</i>	0.968**	-0.930**
<i>Apis cerana</i>	0.947**	-0.810**
<i>Apis dorsata</i>	0.949**	-0.940**
<i>Apis florea</i>	0.999**	-0.925**
<i>Megachile bicolor</i>	0.968**	-0.886**
Other species	0.976**	-0.850**

\*Correlation is significant at 0.05 level (2 tailed)

\*\* Correlation is significant at 0.01 level (2 tailed)

#### **4.4 Diurnal pattern of bee activity on phalsa flowers on 02-04-2020**

The data presented in Table 6 fig. 4 revealed that population of bees visiting phalsa flowers was significantly much higher than those observed on 25-03-2020. The bee visitation pattern followed the same trend as observed on 25-03-2020. Correlation analysis of data table 7 also revealed that bee activity was significantly positively correlated with temperature and significantly negatively correlated with relative humidity.



**Fig. 4. Diurnal pattern of insect pollinators on phalsa flowers in relation to abiotic factors on 02 April 2020**

**Table 6. Diurnal pattern of insect pollinators on phalsa flowers in relation to abiotic factors on 2<sup>nd</sup> April 2020**

Observation (h)	Number of bees/5 branches/5min						Temperature (°C)	Relative humidity (%)
	<i>A.mellifera</i>	<i>A.cerana</i>	<i>A.dorsata</i>	<i>A.florea</i>	<i>M. bicolor</i>	Others		
0900-1000	2.92 ± 0.51	2.20 ± 0.42	1.25 ± 0.06	0.96 ± 0.18	2.10 ± 0.32	2.18 ± 0.32	27	36
1000-1100	3.25 ± 0.62	2.35 ± 0.36	1.40 ± 0.03	1.12 ± 0.24	2.45 ± 0.22	2.84 ± 0.42	28	34
1100-1200	3.48 ± 0.76	2.50 ± 0.28	1.78 ± 0.08	1.35 ± 0.31	2.90 ± 0.28	3.15 ± 0.44	28.2	33
1200-1300	4.10 ± 0.80	2.92 ± 0.26	2.02 ± 0.10	1.65 ± 0.34	3.25 ± 0.62	3.60 ± 0.62	28.5	32
1300-1400	4.78 ± 0.76	3.70 ± 0.33	2.70 ± 0.18	2.15 ± 0.40	3.82 ± 0.58	3.98 ± 0.71	28	30
1400-1500	4.00 ± 0.68	3.05 ± 0.22	2.10 ± 0.22	1.60 ± 0.18	3.08 ± 0.52	3.25 ± 0.58	30	26
1500-1600	3.45 ± 0.63	2.57 ± 0.12	1.68 ± 0.12	1.16 ± 0.12	2.42 ± 0.36	2.55 ± 0.44	28.4	30
Mean ± S.D	3.71 ± 0.68	2.76 ± 0.28	1.85 ± 0.11	1.43 ± 0.25	2.86 ± 0.41	3.08 ± 0.50	28.3	31.57

**Table 7. Correlation between bee visitation on phalsa flowers with abiotic factors on 02 April 2020**

Bee species	Temperature (°C)	Relative humidity (%)
<i>Apis mellifera</i>	0.421*	-0.628**
<i>Apis cerana</i>	0.399*	-0.655**
<i>Apis dorsata</i>	0.425*	-0.658**
<i>Apis florea</i>	0.367*	-0.567**
<i>Megachile bicolor</i>	0.389*	-0.539**
Other species	0.395*	-0.481**

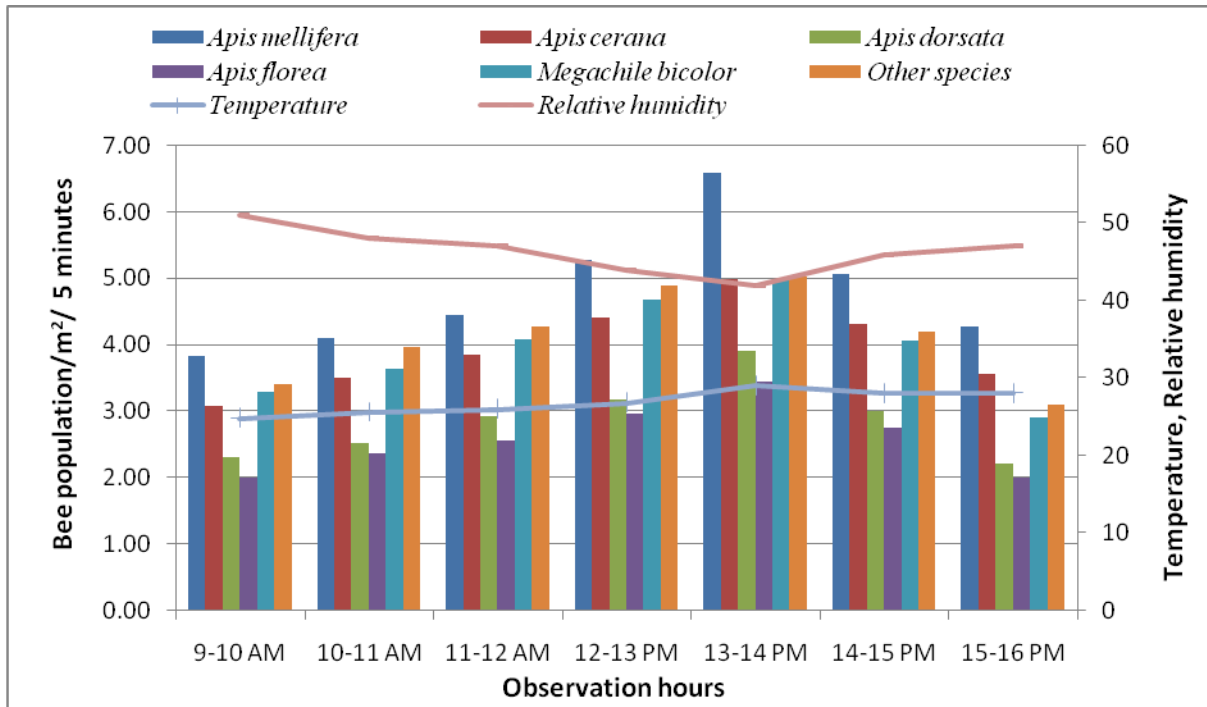
\*Correlation is significant at 0.05 level (2 tailed)

\*\* Correlation is significant at 0.01 level (2 tailed)

Degree of Freedom =  $n - 2 = 33$

#### 4.5 Diurnal pattern of bee activity on phalsa flowers on 08-04-2020

The data presented in Table 8 fig. 5 shows that bee activity followed the same general pattern as observed on earlier days of observations. The bee activity increased with increase in temperature and decreased with relative humidity. The pattern was confirmed by data presented in table 9 which showed that bee activity was significantly influenced by increased in temperature showing significant positive correlation with bees and significantly negative correlation with relative humidity.



**Fig. 5. Diurnal pattern of insect pollinators on phalsa flowers in relation to abiotic factors on 08 April 2020**

**Table 8. Diurnal pattern of insect pollinators on phalsa flowers in relation to abiotic factors on 8<sup>th</sup> April 2020**

Observation (h)	Number of bees/5 branches/5min						Temperature (°C)	Relative humidity (%)
	<i>A.mellifera</i>	<i>A.cerana</i>	<i>A.dorsata</i>	<i>A.florea</i>	<i>M. bicolor</i>	Others		
0900-1000	3.85 ± 0.72	3.08 ± 0.48	2.32 ± 0.32	2.00 ± 0.14	3.30 ± 0.36	3.42 ± 0.29	24.8	51
1000-1100	4.10 ± 0.82	3.50 ± 0.52	2.52 ± 0.36	2.37 ± 0.16	3.64 ± 0.48	3.97 ± 0.33	25.6	48
1100-1200	4.45 ± 0.72	3.85 ± 0.72	2.92 ± 0.42	2.56 ± 0.21	4.08 ± 0.26	4.28 ± 0.42	26	47
1200-1300	5.28 ± 0.84	4.42 ± 0.82	3.18 ± 0.18	2.97 ± 0.28	4.68 ± 0.18	4.90 ± 0.54	26.8	44
1300-1400	6.60 ± 1.10	5.00 ± 0.92	3.92 ± 0.24	3.45 ± 0.14	4.99 ± 0.32	5.03 ± 0.50	29	42
1400-1500	5.07 ± 0.92	4.32 ± 0.62	3.00 ± 0.31	2.75 ± 0.12	4.06 ± 0.32	4.20 ± 0.46	28	46
1500-1600	4.28 ± 0.48	3.57 ± 0.42	2.22 ± 0.28	2.00 ± 0.23	2.92 ± 0.22	3.10 ± 0.39	28	47
Mean ± S.D	4.80 ± 0.80	3.96 ± 0.64	2.87 ± 0.30	2.59 ± 0.18	3.95 ± 0.30	4.13 ± 0.41	26.88	46.42

**Table 9. Correlation between bee visitation on phalsa flowers with abiotic factors on 08 April 2020**

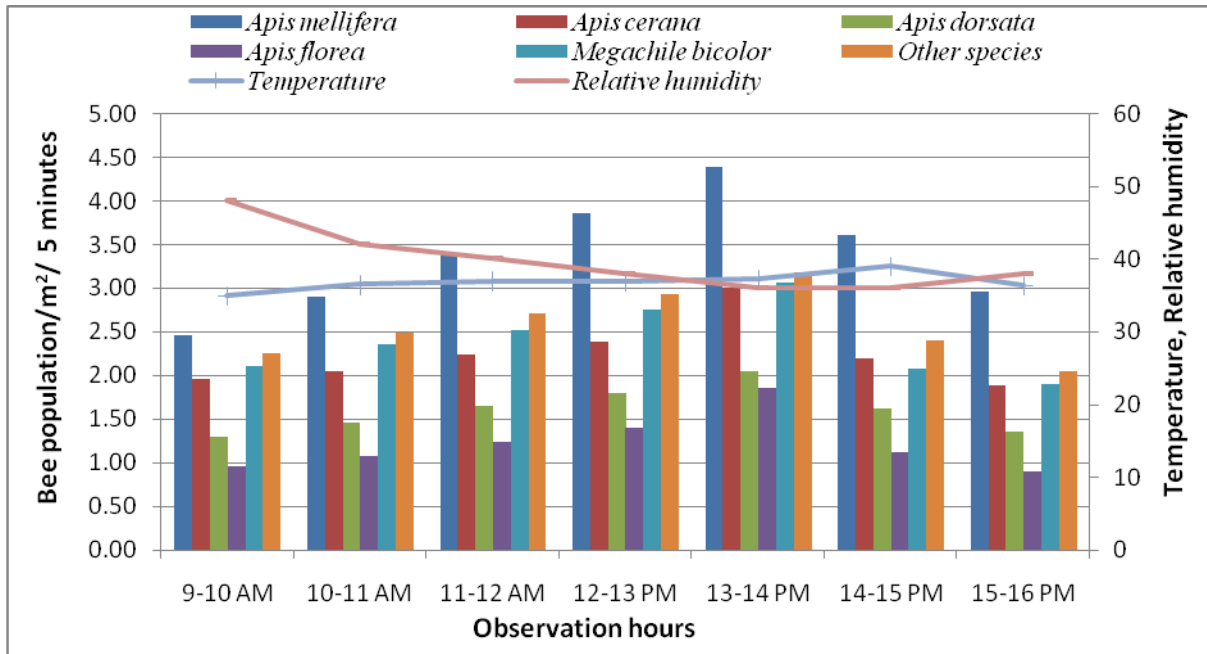
<b>Bee species</b>	<b>Temperature (°C)</b>	<b>Relative humidity (%)</b>
<i>Apis mellifera</i>	0.780**	-0.933**
<i>Apis cerana</i>	0.782**	-0.965**
<i>Apis dorsata</i>	0.594**	-0.875**
<i>Apis florea</i>	0.597**	-0.904**
<i>Megachile bicolor</i>	0.413*	-0.821*
Other species	0.360*	-0.807*

\*Correlation is significant at 0.05 level (2 tailed)

\*\* Correlation is significant at 0.01 level (2 tailed)

#### **4.6 Diurnal pattern of bee activity on phalsa flowers on 15-04-2020**

The data presented in Table 10 fig. 6 revealed that population of bee visiting phalsa flowers was much higher than observed on earlier days of observation. The pattern of bee visitation followed the same trend as increase in temperature but had an inverse trend with relative humidity. Analysis of data table 11 also revealed significant positive correlation of bees with temperature and negative correlation with relative humidity.



**Fig. 6. Diurnal pattern of insect pollinators on phalsa flowers in relation to abiotic factors on 15 April 2020**

**Table 10. Diurnal pattern of insect pollinators on phalsa flowers in relation to abiotic factors on 15<sup>th</sup> April 2020**

Observation (h)	Number of bees/5 branches/5min						Temperature (°C)	Relative humidity (%)
	<i>A.mellifera</i>	<i>A.cerana</i>	<i>A.dorsata</i>	<i>A.florea</i>	<i>M. bicolor</i>	Others		
0900-1000	2.45 ± 0.50	1.95 ± 0.44	1.30 ± 0.14	0.95 ± 0.11	2.10 ± 0.29	2.25 ± 0.29	35	48
1000-1100	2.90 ± 0.58	2.05 ± 0.30	1.45 ± 0.04	1.08 ± 0.13	2.35 ± 0.51	2.48 ± 0.44	36.5	42
1100-1200	3.38 ± 0.70	2.23 ± 0.44	1.65 ± 0.16	1.23 ± 0.15	2.51 ± 0.32	2.71 ± 0.41	37	40
1200-1300	3.85 ± 0.52	2.38 ± 0.48	1.79 ± 0.24	1.40 ± 0.20	2.75 ± 0.56	2.92 ± 0.48	37	38
1300-1400	4.38 ± 0.46	3.00 ± 0.28	2.04 ± 0.21	1.85 ± 0.33	3.06 ± 0.56	3.18 ± 0.51	37.2	36
1400-1500	3.60 ± 0.41	2.19 ± 0.18	1.62 ± 0.23	1.12 ± 0.16	2.08 ± 0.41	2.40 ± 0.46	39	36
1500-1600	2.95 ± 0.33	1.88 ± 0.30	1.35 ± 0.16	0.89 ± 0.19	1.90 ± 0.36	2.05 ± 0.38	36.4	38
Mean ± S.D	3.36 ± 0.50	2.24 ± 0.34	1.60 ± 0.16	1.22 ± 0.18	2.39 ± 0.43	2.57 ± 0.42	36.87	39.71

**Table 11. Correlation between bee visitation on phalsa flowers with abiotic factors on 15 April 2020**

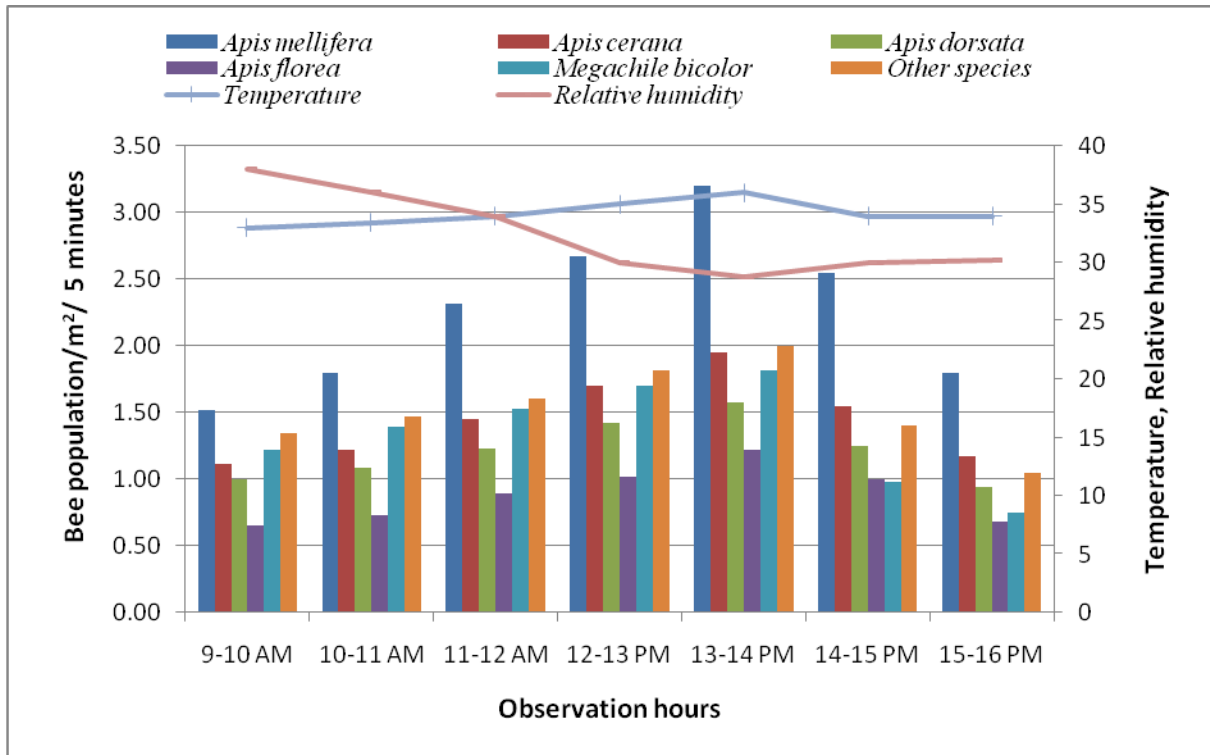
<b>Bee species</b>	<b>Temperature (°C)</b>	<b>Relative humidity (%)</b>
<i>Apis mellifera</i>	0.639	-0.810*
<i>Apis cerana</i>	0.350	-0.534
<i>Apis dorsata</i>	0.511	-0.668
<i>Apis florea</i>	0.313	-0.514
<i>Megachile bicolor</i>	0.140	-0.342
Other species	0.277	-0.418

\*Correlation is significant at 0.05 level (2 tailed)

\*\* Correlation is significant at 0.01 level (2 tailed)

#### **4.7 Diurnal pattern of bee activity on phalsa flowers on 23-04-2020**

The data presented in Table-12 fig. 7 showed that bee population was relatively less as compared to earlier days of observation but followed the same general pattern as observed on earlier days of observation. Correlation analysis of data table 13 revealed that bee activity correlated significantly and positively with temperature and negatively with relative humidity.



**Fig. 7. Diurnal pattern of insect pollinators on phalsa flowers in relation to abiotic factors on 23 April 2020**

**Table 12. Diurnal pattern of insect pollinators on phalsa flowers in relation to abiotic factors on 23<sup>rd</sup> April 2020**

Observation (h)	Number of bees/5 branches/5min						Temperature (°C)	Relative humidity (%)
	<i>A.mellifera</i>	<i>A.cerana</i>	<i>A.dorsata</i>	<i>A.florea</i>	<i>M. bicolor</i>	<i>Others</i>		
0900-1000	1.52 ± 0.29	1.12 ± 0.32	1.00 ± 0.12	0.65 ± 0.12	1.22 ± 0.07	1.35 ± 0.30	33	38
1000-1100	1.80 ± 0.24	1.22 ± 0.18	1.09 ± 0.04	0.73 ± 0.14	1.39 ± 0.12	1.47 ± 0.22	33.4	36
1100-1200	2.32 ± 0.50	1.45 ± 0.32	1.23 ± 0.13	0.89 ± 0.16	1.53 ± 0.19	1.61 ± 0.32	34	34
1200-1300	2.67 ± 0.59	1.70 ± 0.33	1.42 ± 0.29	1.02 ± 0.18	1.70 ± 0.28	1.82 ± 0.43	35	30
1300-1400	3.20 ± 0.48	1.95 ± 0.38	1.58 ± 0.27	1.22 ± 0.30	1.82 ± 0.34	2.00 ± 0.36	36	28.8
1400-1500	2.55 ± 0.22	1.55 ± 0.21	1.25 ± 0.28	1.00 ± 0.14	0.98 ± 0.42	1.40 ± 0.21	34	30
1500-1600	1.80 ± 0.32	1.17 ± 0.26	0.94 ± 0.19	0.68 ± 0.13	0.75 ± 0.17	1.05 ± 0.14	34	30.2
Mean ± S.D	2.27 ± 0.37	1.45 ± 0.28	1.22 ± 0.18	0.88 ± 0.16	1.34 ± 0.22	1.53 ± 0.28	34.2	32.42

**Table 13. Correlation between bee visitation on phalsa flowers with abiotic factors on 23 April 2020**

<b>Bee species</b>	<b>Temperature (°C)</b>	<b>Relative humidity (%)</b>
<i>Apis mellifera</i>	0.921**	-0.770
<i>Apis cerana</i>	0.928**	-0.718
<i>Apis dorsata</i>	0.886**	-0.596
<i>Apis florea</i>	0.893**	-0.717
<i>Megachile bicolor</i>	0.605**	-0.075
Other species	0.762*	-0.314

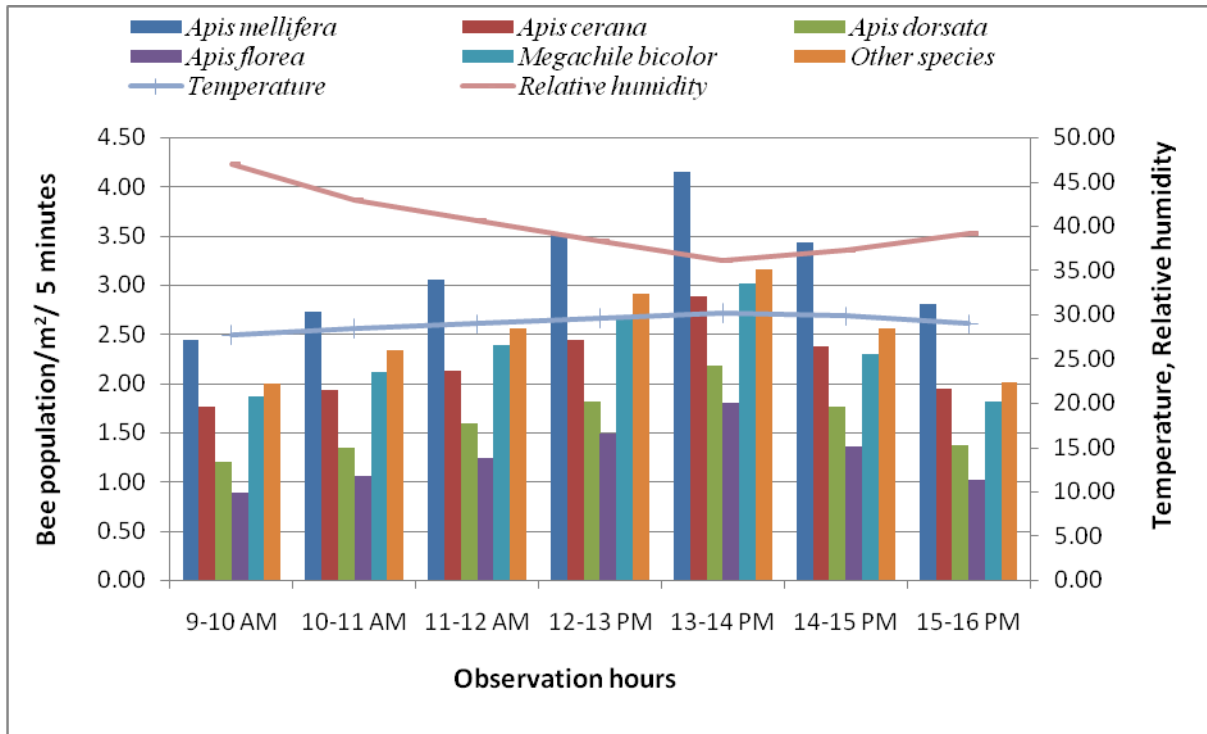
\*Correlation is significant at 0.05 level (2 tailed)

\*\* Correlation is significant at 0.01 level (2 tailed)

#### **4.8 Seasonal pattern of bee visitation with abiotic parameters.**

##### **Overall diurnal pattern of bee activity on 18-03-2020 to 23-04-2020**

The data presented in Table-14 and fig. 8 shows the overall patterns of bee visitation during the entire flowering period of phalsa from 18-03-2020 to 23-04-2020. The data revealed that population was less in the morning hours between 9:00 to 10:00am which increased subsequently attaining peak between 13:00 to 14:00 hours on all days of observations. There was significant increase of population with increase of temperature on all days of observation however, inverse relationship was observed with relative humidity. The data present in table 15 also revealed that all the bee species had significant positive correlation with temperature and negative correlation with relative humidity.



**Fig. 8. Diurnal pattern of insect pollinators on phalsa flowers in relation to abiotic factors during March – April 2020**

**Table 14. Diurnal pattern of insect pollinators on phalsa flowers in relation to abiotic factors w.e.f 18<sup>th</sup> March to 23<sup>rd</sup> April 2020**

Observation (h)	Number of bees/5 branches/5min						Temperature (°C)	Relative humidity (%)
	<i>A.mellifera</i>	<i>A.cerana</i>	<i>A.dorsata</i>	<i>A.florea</i>	<i>M. bicolor</i>	Others		
0900-1000	2.44 ± 0.29	1.77 ± 0.32	1.20 ± 0.12	0.89 ± 0.12	1.87 ± 0.07	2.00 ± 0.30	27.70	47.00
1000-1100	2.73 ± 0.24	1.93 ± 0.18	1.34 ± 0.04	1.06 ± 0.14	2.11 ± 0.12	2.34 ± 0.22	28.48	43.00
1100-1200	3.06 ± 0.50	2.13 ± 0.32	1.60 ± 0.13	1.24 ± 0.16	2.38 ± 0.19	2.56 ± 0.32	28.97	40.67
1200-1300	3.53 ± 0.59	2.44 ± 0.33	1.81 ± 0.29	1.48 ± 0.18	2.68 ± 0.28	2.92 ± 0.43	29.62	38.33
1300-1400	4.15 ± 0.48	2.88 ± 0.38	2.18 ± 0.27	1.80 ± 0.30	3.01 ± 0.34	3.15 ± 0.36	30.20	36.13
1400-1500	3.43 ± 0.22	2.38 ± 0.21	1.76 ± 0.28	1.35 ± 0.14	2.30 ± 0.42	2.56 ± 0.21	29.83	37.33
1500-1600	2.81 ± 0.32	1.95 ± 0.26	1.37 ± 0.19	1.02 ± 0.13	1.82 ± 0.17	2.01 ± 0.14	28.95	39.20
Mean ± S.D	3.16 ± 0.37	2.21 ± 0.28	1.60 ± 0.18	1.26 ± 0.16	2.31 ± 0.22	2.50 ± 0.28	29.10	40.23

**Table 15. Overall correlation between bee visitation on phalsa flowers with abiotic factors during 2020**

Bee species	Temperature (°C)	Relative humidity (%)
<i>Apis mellifera</i>	0.944**	-0.868**
<i>Apis cerana</i>	0.927**	-0.841**
<i>Apis dorsata</i>	0.932**	-0.849**
<i>Apis florea</i>	0.909**	-0.819*
<i>Megachile bicolor</i>	0.798**	-0.680**
Other species	0.829**	-0.716**

\*Correlation is significant at 0.05 level (2 tailed)

\*\* Correlation is significant at 0.01 level (2 tailed)

#### **4.9 Foraging rate of bee species on phalsa flowers**

The data presented in table 16 revealed that on 18-03-2020 *Apis dorsata* visited highest number of flowers per minute (10.25) followed by *Apis cerana* (9.30) , *Apis mellifera* (9.20) and *Megachile bicolor* (4.20). The flower visitation rate of *Apis florea* was (3.2) flower per minute as compared to other bee species. Similar trend was observed on all other days of observation.

**Table 16. Number of flowers visited/ min by different insect species during different days between 13:00-14:00hrs**

<b>Bee visitors</b>	<b>18-03-2020</b>	<b>25-03-2020</b>	<b>02-04-2020</b>	<b>08-04-2020</b>	<b>15-04-2020</b>	<b>Over all observations</b>
<i>Apis dorsata</i>	10.25 ± 1.80	10.02 ± 1.70	9.60 ± 1.20	9.10 ± 1.28	8.60 ± 1.46	9.51 ± 1.48
<i>Apis mellifera</i>	9.20 ± 0.90	9.06 ± 1.24	8.70 ± 0.87	8.20 ± 1.07	7.7 ± 1.32	8.57 ± 1.08
<i>Apis florea</i>	3.20 ± 0.46	2.88 ± 0.28	2.60 ± 0.27	2.20 ± 0.72	1.60 ± 0.46	2.49 ± 0.43
<i>Apis cerana</i>	9.30 ± 1.46	9.44 ± 1.48	9.10 ± 1.28	8.40 ± 1.42	7.50 ± 1.28	8.74 ± 1.38
<i>Megachile bicolor</i>	4.20 ± 0.72	3.92 ± 0.92	3.80 ± 0.48	3.10 ± 0.41	2.50 ± 0.48	3.50 ± 0.60

Each value is a mean ± S.D of 20 observations

#### 4.10 Effect of insect pollination on quality of fruit set

The data presented in Table 17 showed that fruit set in open pollination (44.0%) was significantly higher than self pollination (30.6%).

**Table 17. Impact of insect pollinations on fruit set**

Treatment	Flowers enclosed	Flowers set fruit	Fruit set (%)
Open pollination	360	160	44.0%
Self pollination	392	120	30.6%

P> 0.01

#### 4.11 Effect of insect pollination on quantity of fruit set

The data presented in Table 18 showed that pollination significantly improved the quality of the fruits. The open pollinated fruits had a fruit weight of 0.75g much higher than self pollination 0.57g. Similarly, the fruit weight was significantly much higher in open pollination 0.65g as compared to self pollination in 0.46g. The result clearly revealed that the insect pollination significantly improved the quality and quantity of fruit production.

**Table 18. Effect of insect pollination on quality of fruits**

Treatment	Fruit weight (g)	Fruit volume (g)
Open pollination	0.75 ± 0.38	0.65 ± 0.12
Self pollination	0.57 ± 0.20	0.46 ± 0.23

P> 0.01

Plate 1: Field view of phalsa orchard and insects visitors on phalsa flowers



(A) *Megachile disjuncta*



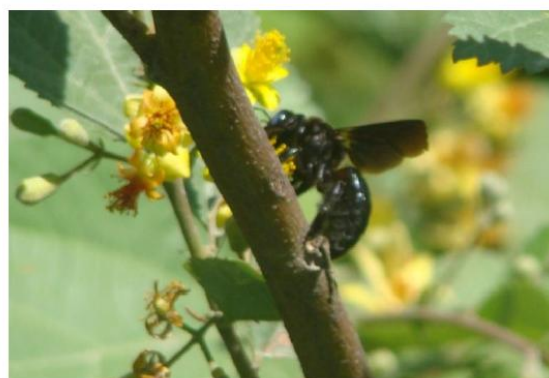
(B) *Ceratina heiroglyphica*



(C) Bees visiting phalsa flowers



(D) *Megachile bicolor*



(E) *Xylocopa pubescens*



(F) Fully Ripened Phalsa

**Plate 2: Field view of phalsa orchard in Raya sub-station**



(A) Phalsa orchard



(B) Ripend of Phalsa fruit



(C) Raya Orchard Farm



(D) Phalsa Plant Trimming



(E) Fully Ripened Phalsa Bunch



(F) Phalsa Fruit

### DISCUSSION

The studies were conducted on phalsa to determine the diversity of insect pollinators there behaviour in relation to abiotic factors and impact of qualitative and quantitative of phalsa. The results obtained or discuss under the following heads:

#### 5.1 Insects visitors of phalsa flowers and there species composition.

Phalsa flowers attracted 9 species of bees belonging to order Hymenoptera (Table 1) they included *Apis mellifera*, *Apis cerana*, *Apis dorsata*, *Apis florea*, *Megachile bicolor*, *Megachile disjuncta*, *Ceratina hieroglyphica*, *Xylocopa fenestrata* and *Xylocopa pubescens*. Off all these bees honeybees comprised more than 74% of total flower visitors. (fig. 1). Similar result was obtained by Parmar 1976 and Manzor-ul-Haq *et al* 1979 to recorded different insect species belonging to Hymenoptera, Lepidoptera and Diptera visiting phalsa flowers. They found that *Apis dorsata* and *Megachile* species were most frequent visitors and considered as the potential pollinators of phalsa. Present finding of diversity of pollinators are in line with Gill *et al.* (2001) who documented a total number of 21 species from the flower of phalsa. Among these *Apis florea*, *Apis mellifera*, *Apis dorsata*, *Megachile bicolor* and *chalicodoma*, *cephalotes* were observed both feeding on nector and pollen. Thapa, (2006) recorded more than 50 species of insect visiting. Kumar (2010) reported *Halictus species* as the most abundance visitors among 3 species of bees. Udikeri *et al* (2019) recorded a total of 19 different insect species visiting phalsa flowers with included 3 species of Megachilidae, 2 species of Vespadae, 5 species of Apidae, 1 species Halictedae and 2 species of Xylocopadae. Akram *et al* (2019) reported the 458 individuals belonging to 18 species in 3 order of insects such as Hymenoptera, Lepidoptera and Diptera visiting phalsa flowers. Of all these insects *Megachile saporus* was the most frequent floral visitor of phalsa flower. Similarly Kumar *et al* (2020) recorded a total of 25 species of insect visiting a phalsa flowers. The study clearly revealed there phalsa however are visited by a variety of insect and there significant varies with each location.

#### 5.2 Diurnal Pattern of insects visitors on phalsa flowers

The studies were conducted on diurnal pattern on bee visitation at weekly intervals the data presented in Figure. 2, 3, 4, 5, 6 and 7 revealed that *Apis mellifera*, *Apis cerana*, *Apis dorsata*, *Apis florea*, *Megachile bicolora* and other species visited phalsa flowers. The

population of these bees species was low in morning hours between 9:00 to 10:00 am which increased there after and attained peak between 13:00 to 14:00 hours the population declined there after and very low population was observed 15:00 to 16:00 hours. The bee population followed the same journal pattern as temperature but was inversely related to relative humidity on all the days of observations. Correlation analysis of the data presented in (Table. 2 – 7). Revealed that bee activity was significantly correlated with temperature and negative correlated with relative humidity.

The overall pattern of bee visitation fig. 8 also revealed the journal pattern that bee visitation low in morning hour's increase between 13:00 to 14:00pm and declined there after. The overall correlation between bee visitation and temperature was significantly positive and negatively with relative humidity (table. 8).

Veeresh kumar *et al* (2020) found that activity of *Megachile* bee started between 8:00 to 9:00 hours and peak foraging activity was obtained between 11:00 to 13:00 hours. The peak foraging activity of apidae was found between 12:00 to 13:00 hours except *Apis florea* which started foraging between 10:00 to 11:00 hours and its maximum abundance between 14:00 to 17:00 hours.

Randhawa and Dass (1962) and Parmar (1976) also found that maximum activity of insects by seen in the morning and noon between 8:00am to 12:00pm. Udikeri and Chandra (2019) recorded peak activity of different bee species at different time of the day. *Halictus species* was most abundance between 14:00 to 16:00 hours. Similarly *Apis dorsata* was most abundance between 10:00 to 12:00 hours. Udikeri and Chandra (2019) recorded peak nector foraging activity of *Apis dorsata*, *Apis mellifera* and *Megachile* species between 10:00 to 12:00 hours. The study clearly revealed that peak of foraging activity differ than different bee species at different location and time of observations.

### **5.3 Foraging behavior of different pollinators in relation to weather factors**

The data present in table 3-8 revealed that all the bee species had significant positive correlation with temperature and negative correlation with relative humidity. There was significant increased in number of bees with increased in temperature during all the days of observations however, activity of bees decrease with increase in humidity.

Foraging rate of bee species phalsa flowers. In earlier studies Szabo (1980) found significant correlation between temperature and flight activity of *Apis mellifera*. However at

the high temperature no correlation was found between two's factor. Benedek and Prener (1972) found that air temperature significantly affected the foraging activity of honeybees. They further reported that flower visiting rate increased increasing air temperature. Cirudarescu (1971) who found that the number of insect visitors on lucerne varied directly with temperature and inversely with relative humidity.

The data presented in (table. 9) revealed that foraging rate were differ for different rate of phalsa flowers. The highest foraging 10.25 flower per minute was observed in followed by *Apis cerana* 9.3, *Apis mellifera* 9.2, *Megachile* 4.2 and *Apis florea* 3.2. Udikeri *et al.* (2018) found that *Apis dorsata* visited 10.01 flowers per minute by spending less time (2.27) second per flower were as *Apis mellifera*, *Halictus* species, *colists* species and *Megachile* species were found visited 9.35, 6.27, 4.16 and 3.92 flower per minute *Apis dorsata* appear to be the most absence pollinator on the phalsa flower. Gill *et al.* (2001) observed that *Apis florea* and *Apis mellifera* spend about 6.3, 8.4, and 8.8 second per flower respectively. Veeresh kumar *et al* (2020) observed that *Megachile bicolora* exhibited a rapid flower visitation rate ( $26.20 \pm 9.45$ ) flowers per minute follow by *Xylocopa latipes* ( $19.93 \pm 4.70$ ) followed by *Megachile* species ( $13.33 \pm 3.03$ ) they further found that *Ceratina* species had a very low a rate of flower visitation ( $2.83 \pm 1.03$ ) flower per minute. The study clearly showed that florng visitors varied significantly with respect to time spend per flower and the number of flowers visitors per minute. The study showed that flower visitation rate and time spend by each species varies from one species to another.

#### **5.4 Effect of bee pollinators on quantitative and qualitative parameters of Phalsa**

Effect of pollination on quality and quantity of fruit production. The data present in Table in showed that fruit set in open pollination (44%) was significantly higher than self pollinations (35.6%) although phalsa flower are hermaphrodite but cross pollination was essential fruit set. Gill *et al.* (2001) found that fruit set (61.6%) in open pollination was significantly higher than self pollination (23.00%).

Udikeri and Chandra (2019) also reported highest fruit set (59.17%) in bee pollination, 47.16% in open pollination and 33.25% in self pollination. Plants follow by open pollination plants under kumargunj agro climatic plants. Beside increase in number of fruit set there was significant improvement in quality of fruit production (Table. 11). The study clearly revealed that insect pollination is important for quality and quantity of fruit production in phalsa.

Veeresh kumar *et al* (2020) reported that fruit set under bee pollinated crop (56.67%) as compared to under bagged conditions (8.95%) were by indicating delayed self pollinations in bagged conditions.

### SUMMARY AND CONCLUSION

The studies were conducted to determine the insect pollinators visiting phalsa flowers, their foraging behaviour in relation to weather parameters and impact of insect pollination on qualitative and quantitative parameters of phalsa. The results obtained revealed that Phalsa flowers attracted insects belonging to four orders which included Hymenoptera, Diptera, Lepidoptera and Coleoptera. Of all these orders, insects belonging to order Hymenoptera were most abundant. They included honey bee *Apis mellifera*, *Apis cerana*, *Apis dorsata*, and *Apis florea*. *Apis mellifera* was represented in large number followed by *Apis cerana*, *Apis dorsata*, and *Apis florea*. Honeybee in general comprised of more than 75% of the total flower visitors. The phalsa flowers were also visited by solitary bees such as Leaf cutter bees *Megachile bicolor* and *Megachile disjuncta* which were more than 14% of the total flower visitors. The other flower visitors included Halictid bee such as *Ceratina hieroglyphica* and Carpenter bee such as *Xylocopa fenestrata*, *Xylocopa pubescens* and other species such as *Eratalis tenax*, *Episyrrhus balteatus*, *Metasyrrhus corolla*, *Eristalis spp.*, *Papilio demoleus*, *Junomia spp.*, *Coccinella septem*. The other flower visitors were fewer in numbers as compared to honey bees and solitary bees. The percentage composition of different insects on phalsa flowers showed that honey bees were most abundant flower visitors and comprised almost 75% of flower visitors followed by leaf cutter bee, Halictid bee, carpenter bee and other flower insects which comprised less than 25% of the total flower visitors. The overall abundance of insect visitors was in the order: *Apis mellifera* > *Apis cerana* > *Apis dorsata* > *Apis florea* > *Megachile bicolor* > *Megachile disjuncta* > *Ceratina hieroglyphica* > *Xylocopa fenestrata* > *Xylocopa pubescens*.

The study conducted on bees visiting on phalsa flowers in relation with abiotic factors revealed that *Apis mellifera*, *Apis cerana*, *Apis dorsata*, *Apis florea*, *Megachile bicolor* and other species visited the phalsa flowers. *Apis mellifera* was most abundant followed by *Apis cerana*, *Apis dorsata*, *Apis florea*, *Megachile bicolor* and other species. The population of all the honey bee species was low in the morning hours i.e., 09:00 to 10:00 hours which increased 10 am onwards and attained peak between 13:00 to 14:00 hours. The population declined thereafter and was low between 15:00 to 16:00 hours. The bee activity clearly showed that increase in population followed the same general pattern as increase in temperature, however, reverse trend was observed with humidity. Correlation analysis of the

data also revealed that bee activity significantly correlated with increasing temperature and showed a significant negative correlation with relative humidity.

Foraging rate of bee species on phalsa flowers varied from one species to another. *Apis dorsata* visited highest number of flowers per minute (10.25) followed by *Apis cerana* (9.30), *Apis mellifera* (9.20) and *Megachile bicolor* (4.20). The flower visitation rate of *Apis florea* was (3.2) flower per minute as compared to other bee species.

Effect of pollination on fruit set showed that fruit set in open pollination (44.0%) was significantly higher than self pollination (30.6%). The studies further revealed that pollination significantly improved the quality of the fruits. The open pollinated fruits had a fruit weight of 0.75g much higher than self pollination 0.57g.

In conclusion, the studies clearly establish that insect pollination is absolutely necessary for qualitative and quantitative improvement in phalsa production. Efforts are needed to conserve pollinators for phalsa production and supplementing the areas with honey bee pollinators where ever pollinators are low or deficient in numbers shall be highly useful.

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## CERTIFICATE-IV

Certified that all necessary corrections as suggested by the external examiner and advisory committee have been duly incorporated in the thesis entitled "**Impact of insect pollination on fruit production in *Grewia asiatica* L.**" submitted by Mr. **Shubham Seth**, Registration No. J-18-M-551.



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