Insect Pollinators of Pumpkin (*Cucurbita pepo* L.) and their Foraging Behaviour

कद्दू (*कुकुरबिटा पेपो* एल.) के कीट परागणकर्ता और उनके खाना ढूंटना व्यवहार कुशल

UMESH S R

Thesis

Master of Science in Agriculture

(Entomology)

2020

DEPARTMENT OF ENTOMOLOGY

RAJASTHAN COLLEGE OF AGRICULTURE

MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND TECHNOLOGY

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Thesis

Submitted to

Maharana Pratap University of Agriculture and Technology, Udaipur

in partial fulfillment of the requirements for the Degree of

Master of Science in Agriculture

(Entomology)

By

UMESH S R

2020

CERTIFICATE-I

CERTIFICATE OF ORIGINALITY

The research work embodied in the thesis titled **"Insect Pollinators of Pumpkin (*Cucurbita pepo* L.) and their Foraging Behaviour"** submitted for the award of degree of M.Sc. (Ag.) Entomology to Maharana Pratap University of Agriculture and Technology, Udaipur (Rajasthan), is original and bonafide record of research work carried out by me under the supervision of **Dr. Anil Vyas** (Assistant Professor, Department of Entomology, Rajasthan College of Agriculture, Udaipur). The contents of the thesis, either partially or fully, have not been submitted or will not be submitted to any other institute or university for the award of any degree or diploma.

The work embodied in the thesis represents my ideas in my own words and where others ideas or words have been included. I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the university and can also evoke panel action from the source which have thus not been properly cited or from whom proper permission has not been taken when needed.

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This is to certify that this thesis entitled **"Insect Pollinators of Pumpkin (*Cucurbita pepo* L.) and their Foraging Behaviour"** submitted for the degree of Master of Science in Agriculture in the subject of Entomology, embodies bonafide research work carried out by **Mr. Umesh S R** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of this thesis was also approved by the advisory committee on 20/08/2020. The manuscript has been subjected to plagiarism check by Urkund Software. It is certified that as per the check, the similarity index of the content is 7% and is within permissible limit as per the MPUAT guidelines on checking plagiarism.

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Dated: / /2020

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This is to certify that **Mr. Umesh S R** student of **Master of Science in Agriculture, Department of Entomology**, Rajasthan College of Agriculture, Udaipur has made all corrections/ modifications in the thesis entitled **"Insect Pollinators of Pumpkin (*Cucurbita pepo* L.) and their Foraging Behaviour"** which were suggested by the external examiner and the advisory committee in the oral examination held on 27/10/2020. The final copies of the thesis duly bound and corrected were submitted on / /2020.

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Date: 29/08/2020

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1. INTRODUCTION

Pumpkin, *Cucurbita pepo* L. belongs to the family Cucurbitaceae and is grown extensively during *kharif* and summer season throughout India. The word pumpkin originates from the Greek word Pepon meaning large melon and refers to the broader category of summer squashes. Pumpkin is grown primarily in the warmer areas of the world especially in the tropics and subtropics. It thrives well in a wide range of soil types with good organic matter. Soil with good drainage and a pH range of 5.5 to 7.5 and a temperature ranging between 20^0C to 30^0C is considered ideal temperature for growing pumpkins for its best vegetative growth. It was brought in to India around 9^{th} century from South America (Pearce and Pearce, 2010). They are limited in temperate regions because of their sensitivity to frost (Tsuchiya and Gupta, 1991).

It is an annual herb with a thick stem, branched, angular and prostrate in habit with tendrils. Vine produces fruits at every node; the leaves have prominent lobes with a prickly surface, with mottled or whitish blotches. Pumpkin plant is monoecious with independent male and female flowers borne on the same plant at different loci (Orzolek *et al.*, 2000). Flowers have bright coloured petals and discharge scent and offer sweet nectar to stimulate insects. The flowers are acuminate in the buds, actinomorphic with a pentamerous perianth. These bright coloured flowers have large seized campanulate petals, which enables perfect landing site for bees. Bearing of small ovary at the base of petals is the identification character of the female flower (Deshpande *et al.*, 1979). The fruit is multiple seeded, fleshy, green coloured in immature stage that changes to brownish-yellow when mature. The fruit has hollowed cavity and contains a sweet fine grained, gelatinous substance sticking to seeds with yellow to orange flesh colour (Thamburaj and Narendrasingh, 2000).

In India the area under pumpkin cultivation is 78,000 ha with a total production is 17.14lakh metric tonnes (Annon. 2018). India is the second largest country producing pumpkin in the world after China. Pumpkin is not only used as a vegetable for cooking (Okoli, 1984), but also has good medicinal properties. It consists of several phyto-constituents like alkaloids, palmitic and flavonoids, oleic and linoleic acids. Medicinal properties including anti-carcinogenic, antioxidant, anti-diabetic, anti-inflammatory and others have been well documented. The seed is becoming popular for its medicinal properties including the prevention of kidney stones and the pulp is used as a plaster to

treat burns and inflammations and as a cooling compress to treat neuralgia and headache. The seed oil is used as salad oil in Europe and, in India for lighting and cooking (Grubben, 2004).

The appearance of pollinators in cross pollination of important agro-horticultural crops are well appreciated. Insect pollination results in a uniform crop and also improves the quality of fruit. Among the 95 per cent cross pollinated flowers, 85 per cent depend on insect pollination (Carruth,1950). Bees are accountable for almost 80 per cent of pollination and their role in increasing crop yields is well recognized (Teale, 1957). Honey bees and some related social Hymenopterans absolutely derive their food in the form of pollen and nectar. The insect pollinators while foraging they incidentally reciprocate by achieving valuable pollination services. The important pollinators are honey bees, bumble bees (*Bombus*), solitary bees (*Xylocopa*, *Andrena*, *Halictus*) stingless bees (*Trigona*, *Melipona*) and many kinds of flies (*Syrphus*, *Bombilius*), black ants, thrips, beetles and moths. The insects belonging to the super-family Apoidea (Hymenoptera) are the most important pollinators of cucurbits.

The plant produces more male flowers which appears first and female flowers appears approximately one week after the first male flower. The flowers are short-lived, longevity is about one-day, blooming at dawn by outward stretching of corolla in both the sexes and closing in most cultivars well before noon. Stigma remains receptive during early hours of the day and set fruit only if pollinated by insects and fruit quality is enhanced by intensive pollinators activity. Male flowers produce nectar and pollen, despite female flowers offer higher quantities of nectar; both male and female flowers produce scent which attracts bees (Surcica, 2011). The high male to female ratio carry out the production of sufficient amount of pollen deposits, thus subsidize in effective pollination.

Pollen must be transferred from male to female flower for fruit set and amount of pollen deposition on stigma is directly proportional to weight and number of fruits (Crane and Walker, 1984). Higher percentage of inferior fruits and reduced yield is due to improper pollination (Mc-Gregor 1976). Hence, visits of insect pollinators are must for maximum pollination, quantity and quality of produce.

Among the various reasons for low yield, insufficient pollinators at bloom are considered to be a major limiting factor. Besides, the pumpkin beetle (*Aulacophora foveicollis*), Caterpillar (*Diaphania indica*), Aphid (*Aphis gossypii*) and Fruit fly

(*Bactrocera cucurbitae*) are also important limiting factors of production, which obviously need to be managed below economic threshold levels by the use of pesticides. Such measures again add to the losses in addition to insufficient insect pollination. Hence, management of beetles and the fruit flies should be done using eco-friendly techniques supporting the beneficial insects like pollinators and natural enemies of pest insects.

Detailed work on foraging behaviour of pollinators of pumpkin is lacking. Though the flowers are visited by several species of bees, recognition of most ideal pollinator, its activity coinciding with time of stigma receptivity and pollen viability, need investigation. In general, botanicals act quickly, degrade rapidly and have, with a few exceptions, low mammalian toxicity. They are environmental friendly and safe to the insect pollinators as compared to the synthetic insecticides.

Looking to these facts as worth exploring and that meagre research work was done on these aspects, the following study on "Insect Pollinators of Pumpkin (*Cucurbita pepo* L.) and their Foraging Behaviour" was proposed with the following objectives:

1. To estimate the diversity of insect pollinators visiting pumpkin flowers.
2. To study the foraging behaviour of major insect pollinators of pumpkin.
3. To evaluate the bio-efficacy of botanicals on the major insect pest of pumpkin and their side effects on the insect pollinators.

2. REVIEW OF LITERATURE

The information available on the present study "Insect Pollinators of Pumpkin (*Cucurbita pepo* L.) and their Foraging Behaviour" is scanty. However, the information pertaining to other cucurbitaceous crops with respect to objectives of this study has been compiled and presented in this chapter.

2.1 Estimating diversity of insect pollinators visiting pumpkin flowers

Nidagundi and Sattagi (2005) reported among the total visiting pollinators in bitter gourd, *Apis florea* was the most predominant species constituting 43%, followed by *A. cerana* (26%), *A. dorsata* (13%) and other pollinators (18%).

Walters and Taylor (2006) observed that there were sufficient natural pollinators [including bumble bees (*Bambus sp.*), carpenter bees (*Xylocopa sp.*), honey bees and squash bees (*Peponapis pruinose* Say)] provided field conditions to induce fruit set of jack-o-lantern pumpkins as fruit number obtained per hectare was not affected by the addition of honey bee colony. Individual pumpkin fruit weights of the *cucurbita pepo*, *C. moschata* and *C. maxima* cultivars evaluated increased about 26%, 70% and 78% respectively, when honey bee colonies were included.

Julifer and Roulston (2009) stated that pumpkin (*c. pepo*) has great potential to be served by wild pollinators because of a reliable and wide spread group of bee species that are commonly associated with their flowers, including bumble bee (*Bambus sp.*), and in the Americas, two genera of specialist ground nesting bees (*Peponapis* and *Xenoglossa*).

Nicodemo *et al.* (2009) reported that *A. mellifera* L. accounted for 73.4% of the visits made by bees, collecting pollen during 34.5 s per flower and nectar in 43.9 s and 29.3 s from female and male flowers of pumpkin respectively and *Trigona spinipes* (Fabr.) collected only nectar, during a mean time of 60.5 s per flower, and represented 26.6% of the visits by bees.

Krug *et al.* (2010) sampled 3.270 bees representing 50 species, with 3.153 bees (24 species) counted during censuses on the *cucurbita* flowers and 117 individuals of 30 species in the pan traps and most abundant bee species was *A. mellifera* (32%) followed by the squash specialist, *Peponapis fevens* (25%).

Kumar (2010) recorded total of 24 insect species visiting bitter gourd flowers *viz*., 11 Hymenopterans, 7 Lepidopterans, 5 Dipterans and 1 Coleopteran. Among these, *Halictus sp*., *Meghachile sp*. and *A. dorsata* were found to be the most frequent pollinators.

Satheesha (2010) recorded 17 species of insect pollinators visiting cucumber flowers. Among these 8-species belonged to order Hymenoptera, 5 species to Diptera, 2 species to Coleoptera and 3 species to Lepidoptera. Among Hymenopterans, honey bees constituted 47.00% of the total insect pollinators visiting cucumber.

Subhakar *et al.* (2011) reported fourteen insect species including 6 hymenopterans, 5 lepidopterans and 3 dipterans were recorded visiting the bitter gourd flowers. Among them *Trigona irridipennis*, *Halictus guturosus* and *A. florea* were the most frequent and abundant visitors. Among all insect visitors, Hymenoptera order constituted the major chunk of pollinators (88.51%) followed by Diptera (5.81%) and Lepidoptera was the least (4.68%). Off total bee population, *T. irridipennis* had the maximum proportion (77.52%) followed by *H. gutturosus* (7.60%).

Kumar *et al*. (2012) observed seven insect visitors on pumpkin plants during the study period. Among the seven insect visitors the ant, *Camponatus compressus* (34.39%), was most prevalent, followed by cucurbit leaf beetle (33.90%) and minimum number of insect visitors including the house fly, followed by small banded swift. Hymenopterans depleted and deposited more pollen compared to other orders.

Bodlah and Waqar (2013) studied the diversity of insect pollinators visiting the summer vegetables *i.e*. Ridge gourd (*Luffa acutangula*), Bitter gourd (*Momordica charantia* L.) and Eggplant (*Solanum melonegema*). The order Hymenoptera include 6 species (*Apis sp*., *Bombus sp*., *Halictus sp*. and two unidentified species 1 from Halictidae family and from Meghachilidae families) and order Diptera include 3 species of pollinators (*Eristalinus sp*. and 1 un-identified species from family Syrphidae and Muscidae each).

Ali *et al.* (2014) stated that pollination in pumpkin (*Cucurbita pepo*) largely depends on activity of native insect pollinators, especially the bees. The insect pollinator community includes 18 species in 3 orders and 6 families in that *Nomia sp*., *A. dorsata* and *Halictus sp*. were among the abundant (189, 399, 117 respectively).

Hanh *et al.* (2014) observed 24 insect species visiting cucumber which includes 12 Hymenopterans, 6 Lepidopterans, 3 Dipterans, 2 Hemipterans and 1 Coleopteran.

Bhowmik and Bhadra (2015) observed insect pollinators belong to 13 families under 5 orders visiting Sunflower. In these orders, Hymenopterans number was maximum (50%) followed by Diptera (17%), Coleoptera (12%), Hemiptera (14%) and Lepidoptera (7%).

Pande and Verma (2016) observed four hymenopteran insect pollinators in pumpkin field *viz*., bumble bee, little honey bee, Indian honey bee and Digger bee. On the basis of abundance and relative abundance bumble bee was identified as most abundant pollinator of pumpkin with 69.69% mean relative abundance as other pollinators mean relative abundance was less than 25% and it was only 3.49% for Indian honey bee.

Shankara *et al.* (2016) recorded 4 orders visiting coriander *viz*. Hymenoptera, Diptera, Lepidoptera and Coleoptera. Among these the important species were *A. dorsata*, *A. Cerana*, *A. mellifera*, *A. florea*, *Syrphus spp*., *Musca spp*. and other Dipteran flies.

Balachandran *et al.* (2017) observed insect pollinators, their visitation frequencies and timings on monsoon cucurbit crops such as *Cucumis sativus* L., *C. pubescens* Willd., *Momordia charantia* L., *Trichosanthes anguina* L. and *Luffa acutangular* L. (Roxb.), in a coastal Karnataka village and also aimed at covering the significance of the surrounding landscape elements in sustaining pollinator elements. Bees, such as *A. dorsata*, *A. cerana*, and *Trigona spp*., were major visitors on all cucurbits, except snake gourd which was pollinated mainly by lepidopterans.

Dorjay *et al.* (2017) studies revealed that cucumber flowers attracted wide varieties of insects belonging to 4 orders, 12 families, 17 genera and 21 species. Bitter gourd flowers also attracted a large number insect belonging to 4 orders, 10 families, 11 genera and 13 species and in this case honey bees such as *A. mellifera*, *A. dorsata* and *A. cerana* were the most important pollinators which comprised more than 69% of the total flower visiting insects.

Gautam and Kumar (2018) recorded 8 insect species visiting ridge gourd flowers *viz*. 5 Hymenopterans, 2 Dipterans and 1 from Odonata. Among these *A. mellifera* L.,

A. dorsata F., *A. florea* F. and *Xylocopa fenestrate* were found to be most frequent pollinators.

Painkra (2018) observed different insect pollinators/visitors in bitter gourd ecosystem *i.e*. *A. dorsata*, *A. indica*, *A. florea*, Xylocopa, Black ant and Small ants were recorded in different fluorescent colored pan trap *i.e.* white, yellow, and blue at different flowering period onset of bloom, full bloom, and end of bloom of bitter gourd.

Belavadi (2019) recorded 16 species of insects belonging to Hymenoptera (81.25%), Diptera (12.50%) and Lepidoptera (6.5%) visiting muskmelon flowers for foraging activity.

Sharma and Meena (2019) recorded 28 insect species belonging to 18 families and 6 orders. Among these insect visitors, 10 species belong to Hymenoptera (53.05%), 8 species of Diptera from 2 families (36.09%) and 3 species from Lepidoptera of 3 families on Coriander crop.

Susan *et al.* (2019) recorded 10 species (4 orders, 8 families) on cucumber flowers. Among these abundance of Hemiptera was maximum (5 species) followed by Hymenoptera (3 species) and Lepidoptera (2 species), while Coleoptera and Diptera were each represented by a single species.

2.2 Study the foraging behaviour of major insect pollinators of pumpkin

Nidagundi and Sattagi (2005) observed the foraging activity of bees on bitter gourd started around 0800 hr and up to 1800 hr at 10 per cent flowering. *Apis dorsata* and *A. florea* were observed foraging from 0800 to 1800 hrs of the day and the highest foraging activity recorded at 1200 hr with 6.68 and 15.44 bees/m^2/5 min, respectively. But the foraging activity of *A. cerana* and other pollinators was maximum at 1000 hr.

Hemanth Kumar (2006) observed the peak activity of *A. cerana* at 0900 hr on pumpkin flower, due to the abundant availability of pollen and nectar, as the flowers started opening between 0700 to 0900 hrs and closed at 1100 hr. The quantity of nectar production increased with the advancement of time and reached peak at 0900 hr thereafter nectar production declined.

Pateel *et al.* (2007) observed the peak activity of *A. dorsata* at 1200 hr which was followed by next peak at 1000 hr and the mean maximum foraging activity of *A. cerana* was at 1000 hr on cucumber flowers.

Thakur and Rana (2008) reported that the foraging activity of insect pollinators was peaked between 0900 and 1000 hrs followed by 1200-1300 hrs and 1500-1600 hrs of the day on cucumber flowers.

Kumar (2010) observed that the foraging activity of *A. dorsata*, *Halictus sp*. and *Meghachile sp*. was commenced at 0600, 0630 and 0700 hr, respectively with peak period at 0800-1000 hrs.

Subhakar *et al.* (2011) reported that foraging activity in bitter gourd was maximum at 0900-1000 hrs of the day. Foraging activity of *Trigona irridipennis*, *A. florea* and *Halictus guturosus* commenced at 0600, 0630 and 0730 hr, respectively with peak at 0900-1000 hrs and ceased by 1400, 1230 and 1300 hr, respectively.

Anooj (2012) observed foraging activity of *A. mellifera* on smooth gourd flowers initiated little earlier in the morning and ceased its activity little earlier in the evening when compared *A. florea* and *Ceratina sp*. Bee population was absent during 1200-1600 hrs of the day due to high relative humidity (>80%) and temperature (>38%).

Kumar *et al.* (2012) reported that during cloudy day activity of ant, *Camponatus compressus,* cucurbit leaf beetle, house fly, small banded swift and hymenopteran insects was found to be high from 0800 h to 1000 h. On rainy days, activity of these insects was found to be high from 0800 h to 1200 h. On sunny days, the activity of these insects was found to be high from 0900 h to 1000 h. Foraging activity of insect visitors showed mostly negative correlation with temperature and positive correlation with relative humidity on cloudy days and sunny days.

Swaraj lakshmi (2013) reported that the peak foraging activity of *A. cerana*, *A. florea* and *T. irridipennis* in ridge gourd was between 0900 and 1100 hr and the other pollinators observed between 1200 and 1600 hr. The time spent by *A. cerana*, *A. florea* and *T. irridipennis* for nectar and pollen collection was maximum at 0900 and 1100 hr of the day. Bodlah and Waqar (2013) also recorded that the higher foraging

activity was during early in the morning i.e., 0600 to 0700 hrs in ridge gourd, bitter gourd and eggplant.

Hanh *et al.* (2014) reported that the peak foraging activity of insect pollinators irrespective of their species was at 0800-1000 hrs of the day.

Shubhakar and Shreedevi (2015) reported that *T. irridipennis* started the foraging activity in bitter gourd at 0600 hr of the day and its mean number increased up to 1000 hr and thereafter decreased with maximum foraging activity at 0900 hr (24.41 bees/m^2/5 min) followed by 1000 hr (21.40 bees/m^2/5 min).

Devika Rani *et al.* (2017) observed that foraging activity *A. dorsata*, *A. mellifera*, *A. florea* and *A. cerana* commenced their pollen collection activity on summer squash flowers at 0600, 0630, 0700 and 0700 hr, with peak period at 0600-0800, 0800-1000, 1000-1200 and 0800-1000 hrs respectively and all of them ceased their activity between 1700-1800 hrs.

Foraging activity period of different honey bee species on *C. moschata* (C-1076) flowers at different day hours during August to September revealed that *A. dorsata*, *A. mellifera*, *A. cerana* and *A. florea* initiated their activity early in the morning at 0530, 0615, 0625 and 0630 hr, respectively and stopped the activity at 1030, 1020, 1025 and 1030 hr of the day, respectively while on *C. moschata* (C-1106) *A. dorsata*, *A. mellifera*, *A. cerana* and *A. florea* initiated their activity early in the morning at 0535, 0615, 0620 and 0625 h, respectively and ceased their activity at 1045, 1025, 1015 and 1040 h of the day, respectively (Lalita and Kumar, 2017).

Hossain *et al.* (2018) studied the foraging activity of insect visitors on cucumber (*C. sativus* L.) and observed that activity of insects was peaked at 0800-0900 hr. The foraging behavior of *A. mellifera* was also studied. The bees spent significantly more time per flower during morning hours (sec/flower) and foraged significantly fewer flowers (7.9 flowers/min) compared to evening hours.

2.3 Evaluation of the bio-efficacy of botanicals on the major insect pest of pumpkin and their side effects on insect pollinators

A standardized, Oil free neem (*Azadirachta indica*) seed extract (NSE) was tested for repellency to honey bees and other pollinators in field applications on blooming canola. However, there were no significant differences in the number of

foraging bees collected in neem-treated, solvent-treated, or untreated canola plots (Naumann, 1994).

Karise *et al.* (2007) reported that neem preparations also affect the foraging behaviour and flight distances of bumble bees, the sub-lethal doses affected the foraging distance of bumble bees.

Singh *et al.* (2010) studied the effect of botanicals *viz.*, *Pongamia globra* Vent (seed oil-1%), *A. indica* (seed kernel extract-5%), formulated neem product (Achook-0.8%), *A. indica* (seed oil-1%) *and A. indica* (leaf extract-10%) on the insect pollinators of coriander. The maximum reduction of insect pollinators (25.06%) was recorded from plots treated with neem seed oil (1%) and 3 days after the pollinator percentage increased in plots treated with NSKE (5%) and neem leaf extract (10%).

Khan *et al.* (2015) conducted studies to assess the repellency (3, 6, 9, 12 and 15hour post treatment) of ethanolic-extracts of *A. indica*, *Eucalyptus camodulensis*, *Melia azedarach, Citrullus colosynthis* at 5, 10 and 15% concentrations against *Aulocophora foveicollis* Lucas adults under laboratory condition with the aim to explore alternatives to synthetic insecticides. *A. indica* and *M. azaderach* exhibited 76.7 and 69.1% repellency.

Dutta *et al.* (2016) evaluate the efficacy of four new generation insecticides along with a botanical against mustard aphid (*Lipaphis erysimi* Kalt.) and their toxicity to coccinellid beetles and foraging honey bees. Among the treatments, Azadirachtin 1EC appeared to be the safest to coccinellid beetles (7.50/5 plants) and foraging honey bees (9.64/plot/5 min).

Neupane and Shreshta (2016) evaluate the efficacy of different concentration (2, 3, 4, 5ml/litre and control) of botanical pesticide multineem against red pumpkin beetle (*Aulocophora foveicollis*). The result showed that 5ml/ litre concentration gave the highest reduction of beetle population (100%) followed by 4ml/litre (91.5%), 3ml/litre (63%) and 2ml/litre (37.9%), respectively.

Rashid *et al.* (2016) studied the effect of three plant extracts *viz.*, Neem seed kernel extract (*A. indica*), *Moringa oleifera*, *Aloe vera* on Red pumpkin beetle (*Aulocophora foveicollis*) in cucurbits. The minimum population (4.31 insects/plant)

and minimum per cent leaf infestation (9.1%/plant) recorded in neem (*A. indica*) treated plots.

Sathua *et al.* (2017) studied the bio-efficacy of three botanicals [namely *Allium sativum* extract, *Allium cepa* extract and NSKE]. Among these botanicals, NSKE 5% caused maximum mortality of 64.50%.

Saleem *et al.* (2019) evaluate the efficiency of biopesticides: matrine, spintoram, azadirichtin and *Annona squamosa* against cotton aphid (*Aphis gossyphi* Glov.) and the two-spotted spider mite, (*Tetranychus urticae* Koch.) and the neem extract showed the efficiency (73% and 56%) reduction against the aphid and the mite, respectively.

3. MATERIALS AND METHODS

A field experiment entitled **"Insect Pollinators of Pumpkin (*Cucurbita pepo* L.) and their Foraging Behaviour"** was conducted during *kharif* 2019 at the Horticulture Farm, Rajasthan college of Agriculture, MPUAT, Udaipur. The details of materials, methodologies and benchmarks adopted for investigation during the course of research are described in this chapter.

3.1 Experimental site

The present investigation was conducted at the Instructional Horticulture Farm and the Department of Entomology, Rajasthan college of Agriculture, MPUAT, Udaipur during *kharif* 2019. Udaipur is located at 24º35' N latitude and 73º42' E longitude at an elevation of 582.17 MSL (Mean Sea Level) in the state of Rajasthan. The region comes under agro-climatic zone IVa *i.e*. "Sub-Humid Southern Plain and Aravalli Hills" of Rajasthan.

3.2 Climate condition of the location

The agro-climatic zone IVa has a typical sub-tropical climatic condition represented by mild winters and moderate summers accompanied with high humidity during the months of July to September. The mean annual rainfall of this tract is around 60 cm, which is contributed by South West monsoon from July to September and intermittent rain during the winter season. The minimum and maximum temperatures range between 21.4 to 24.2 ºC and 27.7 to 33.6 ºC, respectively and the minimum and maximum relative humidity range between 55 to 84.5 per cent and 71.7 to 94.5 per cent, respectively during crop growth period. The total rainfall during the crop season *kharif* 2019 was 729.6 mm.

3.4 Preparation of field and crop raising details

The experimental field was prepared during middle of June, 2019 by ploughing with a disc plough followed by cross-harrowing and planking. Timely weeding and hoeing operations were implemented as per the package of practices (manual weeding was performed at 20 and 30 days after sowing). Recommended doses of N: P: K (70:25:25 kg/ha) were applied to the crop. Half dose of nitrogen and a full dose of phosphorous and potassium fertilizers were applied as basal dose along with FYM. The remaining doses of N were applied in two equal split doses at the time of

plantation and at the time of full blooming. The crop was rainfed, but during periods of dry spell irrigation was given.

3.5 Specific details of the experiment

3.5.1: Estimating diversity of insect pollinators visiting pumpkin flowers

The pumpkin crop cultivated at the Horticulture farm, RCA, Udaipur during *kharif* 2019 was observed for different groups of insect pollinators visiting during flowering at 10 am, 12 noon, 4 pm for five minutes per square meter area during peak flowering period. There were 5 such spots for observation. The data were later averaged according to time wise and insect group wise to infer the pollinator fauna as well as the dominance of a particular group.

The following mathematical analysis was made:

$$\textbf{Relative density (R.D)} = \frac{\text{No. of individuals of the species}}{\text{No. of individuals of all species}} \times 100$$

3.5.2: Study the foraging behaviour of major insect pollinators of pumpkin

This study was carried out during *kharif* season 2019 in the unsprayed plots of the crop raised for studying pollinators fauna.

Observations were made at two hours interval from 0600 to 1600 hr on number of bees visiting each square meter area for five minutes at 5 days intervals from five percent flowering. There were five such spots for each observation. Observations were continued from 5 percent flowering till the spraying of botanicals. Recorded observations were averaged time wise and species wise to draw the conclusion that which species of bees and at what time dominated the other.

3.5.3: Evaluation of the bio-efficacy of botanicals against the major insect pest of pumpkin and their side effects on insect pollinators

Different botanicals were evaluated for their bio-efficacy against pests and their side effect on the insect pollinators. Crop was raised in a field with a plot size of 4 × 2 m with a proposed spacing and the details of the trails are as:

Crop : Pumpkin

Variety : MAHY 1 (MPH-1)

Design : RBD

Replications : 4

Treatments : 6

Total no. of plots : 24

Plot size : 4.0 × 2.0 m

Spacing : 90 × 90 cm

Treatments:

T_1- *Azadirachta* seed kernel extract @ 5% conc.

T_2- *Azadirachta* leaf extract @ 10% conc.

T_3- *Azadirachta* oil @ 1% conc.

T_4- Dusparni (DP) @ 10% conc.

T_5- Teekha sat (TS) @ 3% conc.

T_6- Untreated control.

Applications- once

The number of major pollinators during their peak foraging period was counted one day before treatment and 1, 3 and 5 days after the treatments. The decrease or increase in the insect pollinators population was evaluated 1, 3 and 5 days after the application of botanicals. Later, the reduction in insect population was estimated one day after the spray of the botanicals by using the methodology given by Henderson and Tilton (1955); whereas 3 and 5 days after the spray of botanicals the average per centage increase or decrease in insect pollinator abundance was computed over control. Statistical analysis was used for obtained data wherever necessary.

Henderson and Tilton formula

$$\text{Corrected \%} = \left\{ 1 - \frac{\text{n in Co before treatment x n in T after treatment}}{\text{n in Co before treatment x n in T after treatment}} \right\} \times 100$$

Where: n- insect population, Co- control, T- treated

Preparation of *Azadirachta* Seed Kernel Extract

To prepare neem seed kernel extract (NSKE) the mature kernels of neem were collected and dried in a shady place. The kernels were crushed with the help of a pastel and mortar (brass make). The powder obtained was passed through 60-mesh sieve and then mixed with Luke-warm distilled water on a weight by weight basis taking equal quantities of powder and water. The suspension obtained was considered to be of 100% concentration from which the desired concentration of 5% was prepared by dilution using distilled water.

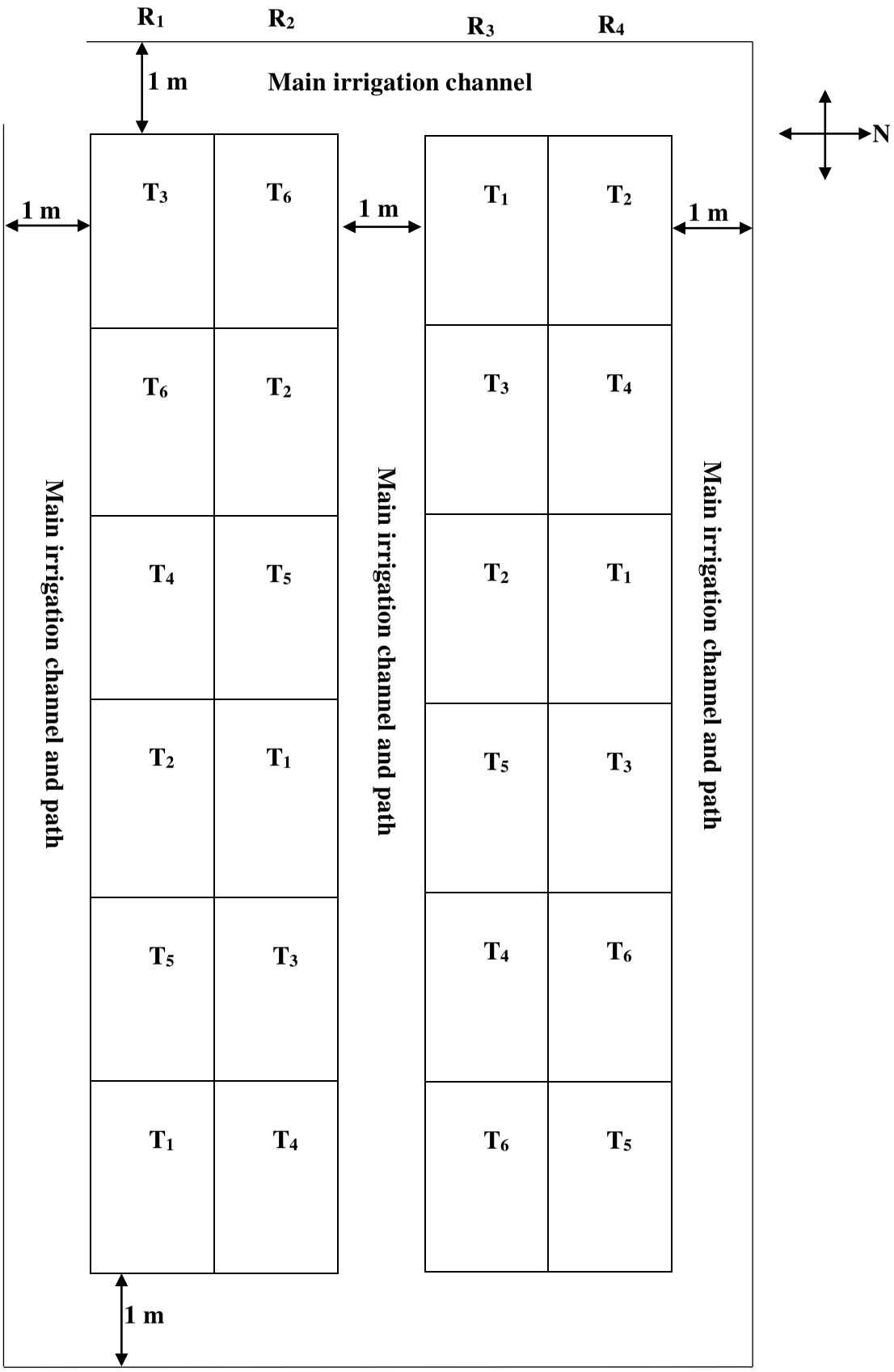
Preparation of *Azadirachta* Leaf Extract

The leaf extract of neem (NLE) was prepared by taking 600g of fresh, tender leaves that were put in a glass container and three litres of lukewarm water were added to it. The leaves were allowed to stand soaked in water for 12 hours and then macerated in a mixer-grinder. The extract was filtered through a muslin cloth and collected in a glass-jar. This extract was considered to be of 20% concentration; later the desired concentration (10%) for the spray was prepared after dilution.

Contents of Dusparni

- 10 lit Cow urine
- 2 kg Cow dung
- 5 Kg Neem leaves
- 2 Kg Karanj leaves
- 2 Kg Custard apple leaves
- 2 Kg Datura leaves
- 2 Kg Basil leaves
- 2 Kg Papaya leaves
- 2 Kg Marigold leaves
- 2 Kg Beal leaves
- 2 Kg Nerium leaves
- 500 g Tobacco leaves
- 500 g garlic
- 500 g Turmeric
- 500 g Green chilli
- 200 g Ginger
- 200 lit water

EXPERIMENTAL FIELD LAYOUT



4. EXPERIMENTAL RESULTS

4.1 Estimating diversity of insect pollinators visiting pumpkin flowers

List of insect pollinators (Table: 1, Plate: 1, Fig: 1) includes honey bees and general pollinators.

The insect pollinators of pumpkin consist of total 7 species. Hymenopterans are the dominant group of pollinators that includes mainly honey bees. Among honey bees, *Apis dorsata* proved to be the dominant one (67.40%) followed by *A. florea* (14.28%). Other hymenopteran pollinators belong to family Halictidae (7.93%) and Sphecidae (3.17%) also shown their presence. The other pollinators include Diptera and Lepidoptera as they together constitute about 6.87%. Among the Dipterans, Syrphidae family members have shown their presence and among the Lepidopterans, butterflies belong to the family Pieridae was recorded on pumpkin as pollinators.

4.2 Study the foraging behaviour of major insect pollinators of pumpkin

4.2.1 Foraging behaviour of *Apis dorsata* on pumpkin

At five per cent flowering, *Apis dorsata* has shown their maximum visit from 0900-1100 hrs. At 0600-0700 hrs, 1.6 bees/m^2/5 min were found. The number increased after 0900 hr and remained more or less same up to 1200 hr and become nil from 1300-1600 hrs. At 0900-1000 hrs, 11.00 bees/m^2/5 min visited the flowers and at 1000-1100 hrs, 9.2 bees/m^2/5 min were found on pumpkin flowers. At 1100-1200 and 1200-1300 hrs, the number of bees visited was 6.4 and 4.6 bees/m^2/5 min, respectively (Table: 2, Plate: 2, Fig: 2).

On 5^{th} day after five per cent flowering, 3.4 bees/m^2/5 min visited flowers at 0600-0700 hrs. At 0800-0900 and 0900-1000 hrs, more bees were visited, 9.6 and 10.2 bees/m^2/5 min, respectively. It was decreased to 3.8 bees/m^2/5 min at 1200-1300 hrs. At 1300-1600 hrs, no bee activity was observed in field.

On 10^{th} day after five per cent flowering, 3.8 bees/m^2/5 min visited the flowers at 0600-0700 hrs which increased to reach high at 0900-1000 and 1000-1100 hrs with the bees visits 13.4 and 9.6 bees/m^2/5 min, respectively. At 0800-0900 and 1100-1200 hrs, the number of bees/m^2/5 min was 5.6 and 6.8, respectively. The least bees were recorded at 1300-1400 hrs with 2.8 bees/m^2/5 min.

On 15th day after five percent flowering, the maximum activity was observed at 0900-1000 hrs counting 12.4 bees/m^2/5 min on pumpkin flowers. At 0600-0700 hrs, 3.2 bees/m^2/5 min were recorded on pumpkin crop. At 0700-0800 and 0800-0900 hrs, 7.8 and 9.2 bees/m^2/5 min visits were recorded, respectively. No activity was seen between 1300-1600 hrs.

Over all, the mean foraging behaviour of *A. dorsata* was less (4.34 bees/m^2/5 min) on 1st day and the maximum foraging activity (5.26 bees/m^2/5 min) was seen on 15th day after five per cent flowering. On 5th and 10th day after five per cent flowering, 5.02 and 4.86 bees/m^2/5 min was recorded, respectively.

Similarly, the mean foraging activity when compared between the different hours of the day, the mean maximum foraging activity was observed between 0900-1000 hrs of the day with 11.75 bees/m^2/5 min and the least was recorded at 0600-0700 hrs with 3 bees/m^2/5 min.

4.2.2 Foraging behaviour of *Apis florea* on pumpkin

On 1st day after five per cent flowering *Apis florea* started foraging activity at 0700-0800 hrs with 0.8 bees/m^2/5 min. Further, the peak activity was recorded at 0800-0900 hrs with 1.6 bees/m^2/5 min and confined up to 0900-1000 hrs with 1.2 bees/m^2/5 min. Further it decreased to 1000-1100 hrs with 0.8 bees/m^2/5 min. At 1100-1300 hrs and 1300-1400 hrs, the number of visits was 0.6 and 0.4 bees/m^2/5 min, respectively and at 1400-1600 hrs of the day no bee activity was observed in the field (Table: 3, Plate: 3, Fig: 3).

On 5th day after five per cent flowering, *A. florea* foraging activity was peak at 0800-0900 hrs with 1.8 bees/m^2/5 min. At 0700-0800 hrs, 0.6 bees/m^2/5 min were found visiting the pumpkin crop and at 0900-1000 hrs and 1000-1100 hrs, the number of bee visits was 0.8 and 0.6 bees/m^2/5 min, respectively. Further, 0.2 bees/m^2/5 min were observed at 1100-1300 hrs on the pumpkin flowers and from 1300-1600 hrs, no bee activity was observed.

On 10th day after five per cent flowering, *A. florea* have shown their peak visit at 0800-0900 hrs. At 0700-0800 and 0900-1100 hrs, the number of visits was 1.4 bees/m^2/5 min. At 1100-1200 and 1200-1300 hrs, 0.6 and 0.4 bees/m^2/5 min were found visiting the pumpkin crop, respectively.

Table 1. Pollinator fauna of pumpkin

Sl.no	Name of Pollinator	Systemic position	% Relative abundance
1.	*Apis dorsata* F.	Hymenoptera: Apidae	67.40
2.	*Apis florea* F.	Hymenoptera: Apidae	14.28
3.	*Halictus sp*.	Hymenoptera: Halictidae	4.76
4.	*Lasioglosum sp*.	Hymenoptera: Halictidae	3.17
5.	Sphecid wasp	Hymenoptera: Sphecidae	3.17
6.	Syrphid fly	Diptera: Syrphidae	5.55
7.	*Pieris brassicae*	Lepidoptera: Pieridae	1.32

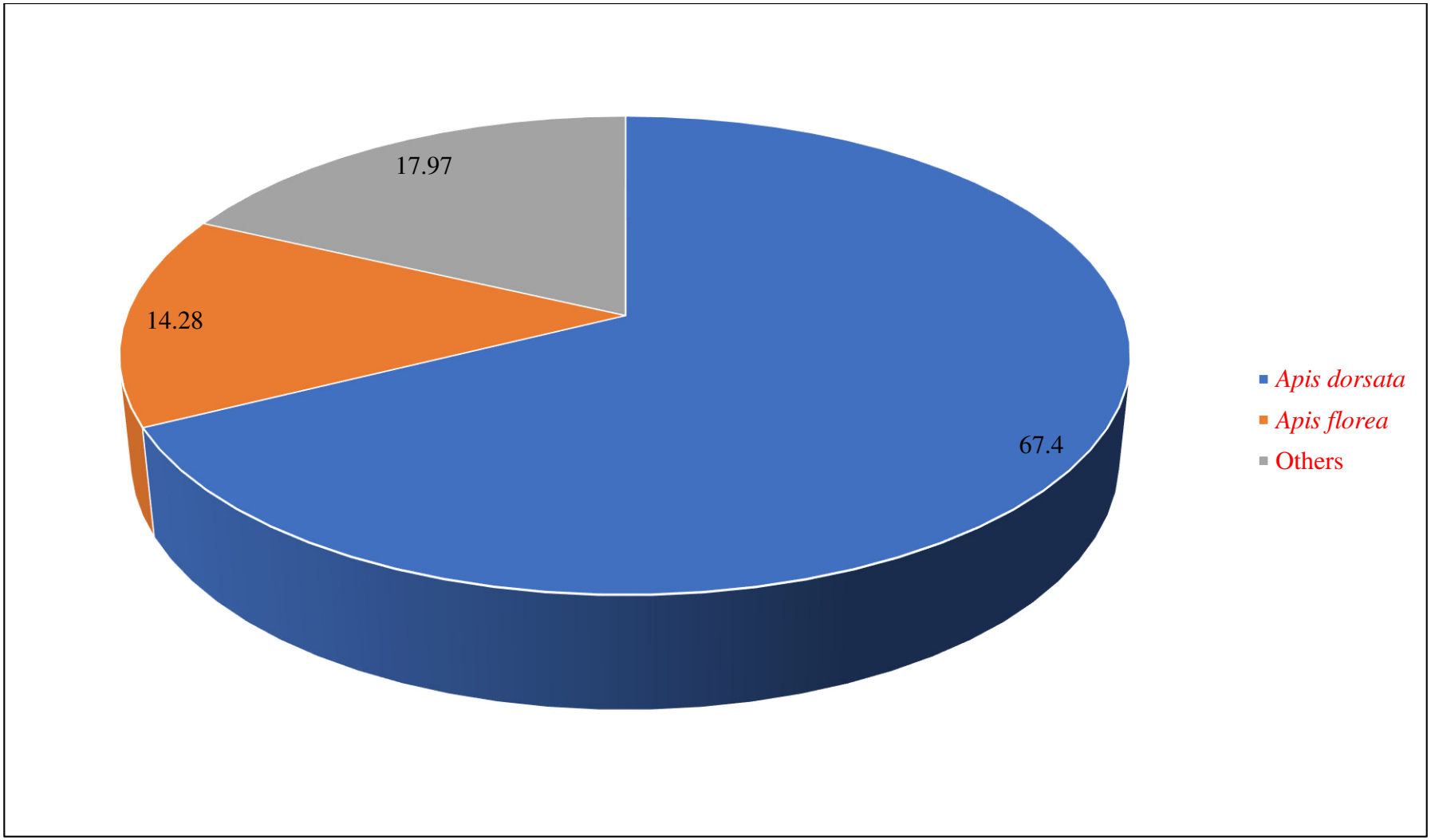


Fig. 1: Pollinator fauna (%) on pumpkin

Apis dorsata

Apis florea

Halictus sp.

Lasioglosum sp.

Plate 1: Flower visitors of pumpkin

Table 2. Foraging behaviour of *Apis dorsata* on pumpkin

Hours of the day	Number of bees/m^2/5 min				Total	Mean
	1DAF	5DAF	10DAF	15DAF		
0600-0700	1.6	3.4	3.8	3.2	12	3
0700-0800	5.2	6	6.6	7.8	25.6	6.4
0800-0900	5.4	9.6	5.6	9.2	29.8	7.45
0900-1000	11	10.2	13.4	12.4	47	11.75
1000-1100	9.2	8.2	9.6	8.4	35.4	8.85
1100-1200	6.4	9	6.8	8.2	30.4	7.6
1200-1300	4.6	3.8	2.8	3.4	14.6	3.65
1300-1400	0	0	0	0	0	0
1400-1500	0	0	0	0	0	0
1500-1600	0	0	0	0	0	0
Total	43.4	50.2	48.6	52.6		
Mean	4.34	5.02	4.86	5.26		

DAF- Days after five per cent flowering

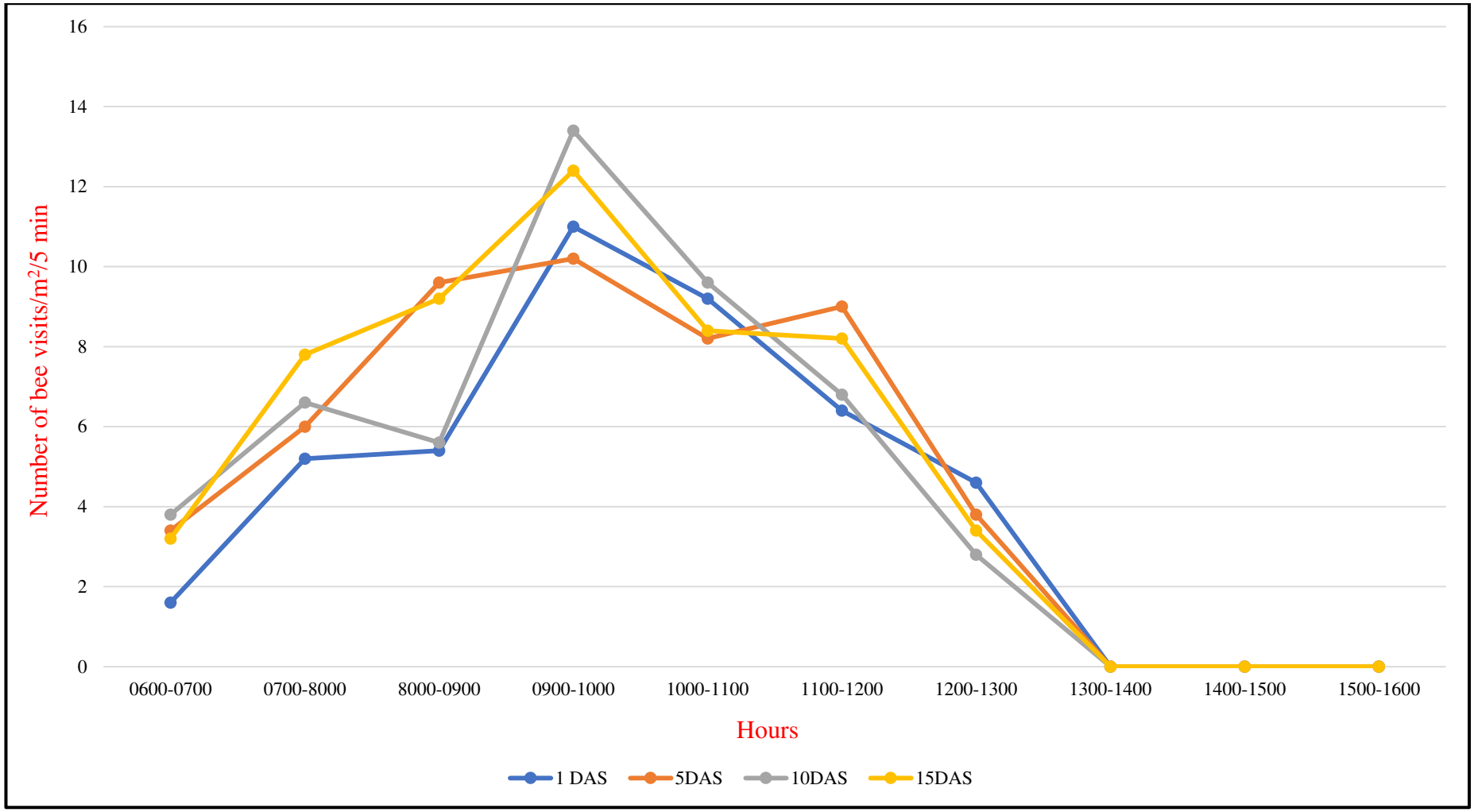


Fig. 2: Foraging activity of *Apis dorsata* on pumpkin during different hours of the day

Plate 2: ***Apis dorsata*** **foraging on pumpkin flowers**

Plate 3: ***Apis florea*** **foraging on pumpkin flowers**

Table 3. Foraging behaviour of *Apis florea* on pumpkin

Hours of the day	Number of Bees/m^2/5 min				Total	Mean
	1DAF	5DAF	10DAF	15DAF		
0600-0700	0	0	0	0	0	0
0700-0800	0.8	0.6	1.4	1.6	4.4	1.1
0800-0900	1.6	1.8	2	2.4	7.8	1.95
0900-1000	1.2	0.8	1.4	1	4.4	1.1
1000-1100	0.8	0.6	1.4	0.6	3.4	0.85
1100-1200	0.6	0.2	0.6	0.6	2	0.5
1200-1300	0.6	0.2	0.4	0.4	1.6	0.4
1300-1400	0.4	0	0.2	0	0.6	0.15
1400-1500	0	0	0	0	0	0
1500-1600	0	0	0	0	0	0
Total	6	4.2	7.4	6.6		
Mean	0.6	0.42	0.74	0.66		

DAF- Days after five per cent flowering

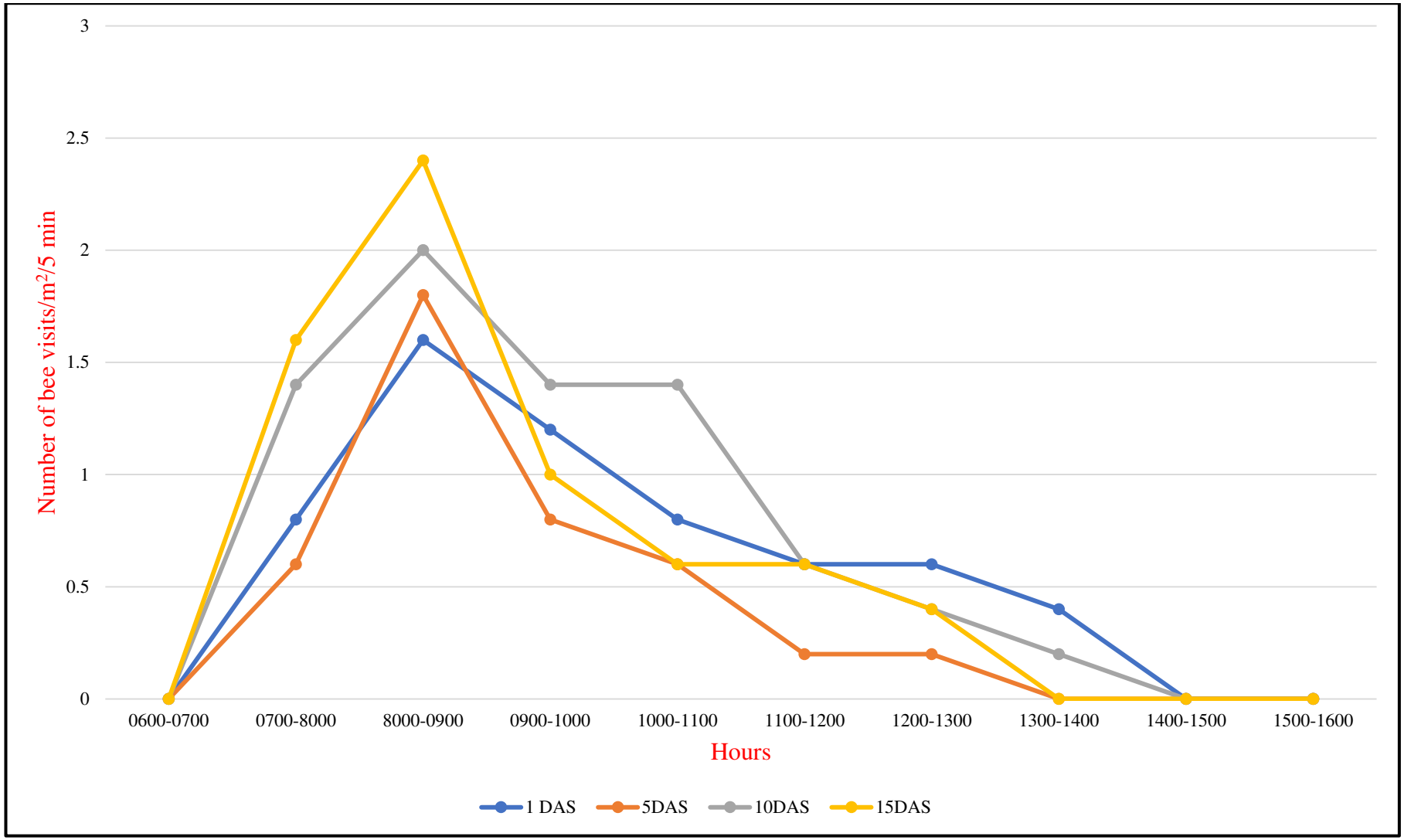


Fig. 3: Foraging activity of *Apis florea* on pumpkin during different hours of the day

On 15th day after five per cent flowering, the peak foraging activity was observed at 0800-0900 hrs with 2.4 bees/m^2/5 min. The foraging activity started at 0700-0800 hrs with 1.6 bees/m^2/5 min and started decreasing towards evening with 0.4 and 0.00 bees/m^2/5 min at 1200-1300 and 1300-1600 hrs, respectively.

Over all, the mean foraging behaviour of *A. florea* was less (0.6 bees/m^2/5 min) on 1st day and least was recorded on 5th day with 0.42 bees/m^2/5 min. The maximum foraging activity was recorded on 10th day with 0.74 bees/m^2/5 min. Further it decreased on 15th day to 0.66 bees/m^2/5 min.

Similarly, the mean foraging activity of *A. florea* when compared between the different hours of the day, the maximum activity was noticed at 0800-0900 hrs of the day with 1.95 bees/m^2/5 min. It was recorded less at 1300-1400 hrs of the day with 0.15 bees/m^2/5 min and least at 0600-0700 and 1400-1600 hrs with 0.00 bees/m^2/5 min.

4.3 Evaluation of the bio-efficacy of botanicals on the major insect pest of pumpkin and their side effects on insect pollinators

4.3.1 Side-effects of botanicals on the major insect pollinators of pumpkin

The study on the side-effects of botanicals on the number of major insect pollinators of pumpkin, one day after the spray (Table: 4, Fig, 4), it could be recorded that the average number of insect pollinators visiting pumpkin crop were less in all the treatments with botanicals when compared with pre-treatment population recorded one day before the spray. Three days after the spray with botanicals, the average number of insect pollinators was more in all treatments except in Teekha sat (3%) when compared with one day after the spray and when compared with pre-treatment, the average number of insect pollinators was less in all treatments except in *Azadirachtin* seed kernel extract (5%) and *Azadirachtin* leaf extract (10%). In *Azadirachtin* seed kernel extract (5%) the average number of insect pollinators were same as pre-treatment, but in *Azadirachtin* leaf extract (10%) there was a slight increase in number of pollinators. Five days after the spray, average number of insect pollinators was more in *Azadirachtin* seed kernel extract (5%) and *Azadirachtin* leaf extract (10%), but in *Azadirachtin* oil (1%), Dusparni (10%) and Teekha sat (3%) there was a decrease in the mean number of insect pollinators.

When a comparison was made between treatments and control with regard to insect pollinator population (Table: 5), one day after the spray of botanicals on pumpkin crop against red pumpkin beetle (*Raphidopalpa foveicollis*), the side-effect of the botanicals was showed a decrease in insect pollinator intensity ranging from 7.95 to 20.45%. On first day after the spray of botanicals, the reduction in insect pollinators was seen in all treatments. The minimum reduction was seen in the plots treated with *Azadirachtin* seed kernel extract (5%) (-7.95%) and the maximum reduction was seen in the plots treated with *Azadirachtin* oil (1%) (-20.45%). However, the reduction in insect pollinator intensity was significant among the treatments. On third day after the spray of botanicals, the insect pollinator intensity expressed in per cent was increased in the plots treated with *Azadirachtin* seed kernel extract (5%) and *Azadirachtin* leaf extract (10%), while they decreased in the plots treated with *Azadirachtin* oil (1%), Dusparni (10%) and Teekha sat (3%). On fifth day after the spray, the maximum reduction in insect pollinator intensity was seen in the plots treated with *Azadirachtin* oil (1%) (-17.07%) and the maximum increase was seen in the plots treated with *Azadirachtin* seed kernel extract (5%) (13.41%). The plots treated with Dusparni (10%) was shown 10.97% decrease in insect pollinator intensity, whereas *Azadirachtin* leaf extract (10%) and Teekha sat (3%) was shown 6.09 and 2.43% increase in insect pollinator intensity, respectively.

4.3.2 Effect of botanicals on the major insect pest of pumpkin

The bio-efficacy of some botanicals are evaluated against major insect pest of pumpkin *i.e.* Red pumpkin beetle (*Raphidopalpa foveicollis*). In these botanicals, *Azadirachtin* seed kernel extract (5%) observed to be more effective against red pumpkin beetle followed by *Azadirachtin* leaf extract (10%). The table: 6, fig: 5 shows that minimum number of red pumpkin beetle/m^2 was found in the plot treated with *Azadirachtin* seed kernel extract (5%) (1.31) and *Azadirachtin* leaf extract (10%) (1.57). The maximum number of red pumpkin beetle was found in the plots of control, which were 2.28 beetles/m^2. In botanical treated plots, the maximum number of beetles/m^2 were recorded in the plots treated with Dusparni (10%) (1.91), Teekha sat (3%) (1.86) and *Azadirachtin* oil (1%) (1.78).

Table 4. Effect of botanicals on the intensity of Honey bee pollinators of pumpkin (Numbers/m^2/5 min)

Treatments	Pre-treatment	Mean insect-pollinator intensity		
		Post-treatment		
		I day	III day	V day
***Azadirachtin* seed kernel extracts (5%)**	22	20.25	22	23.25
***Azadirachtin* leaf extracts (10%)**	20.25	18.75	20.5	21.75
***Azadirachtin* oil (1%)**	21.75	17.5	18.25	17
Dushparni (10%)	20	18.25	18.75	18.25
Teekha sat (3%)	21.5	20	19.5	21
Control	20.75	22	20	20.5

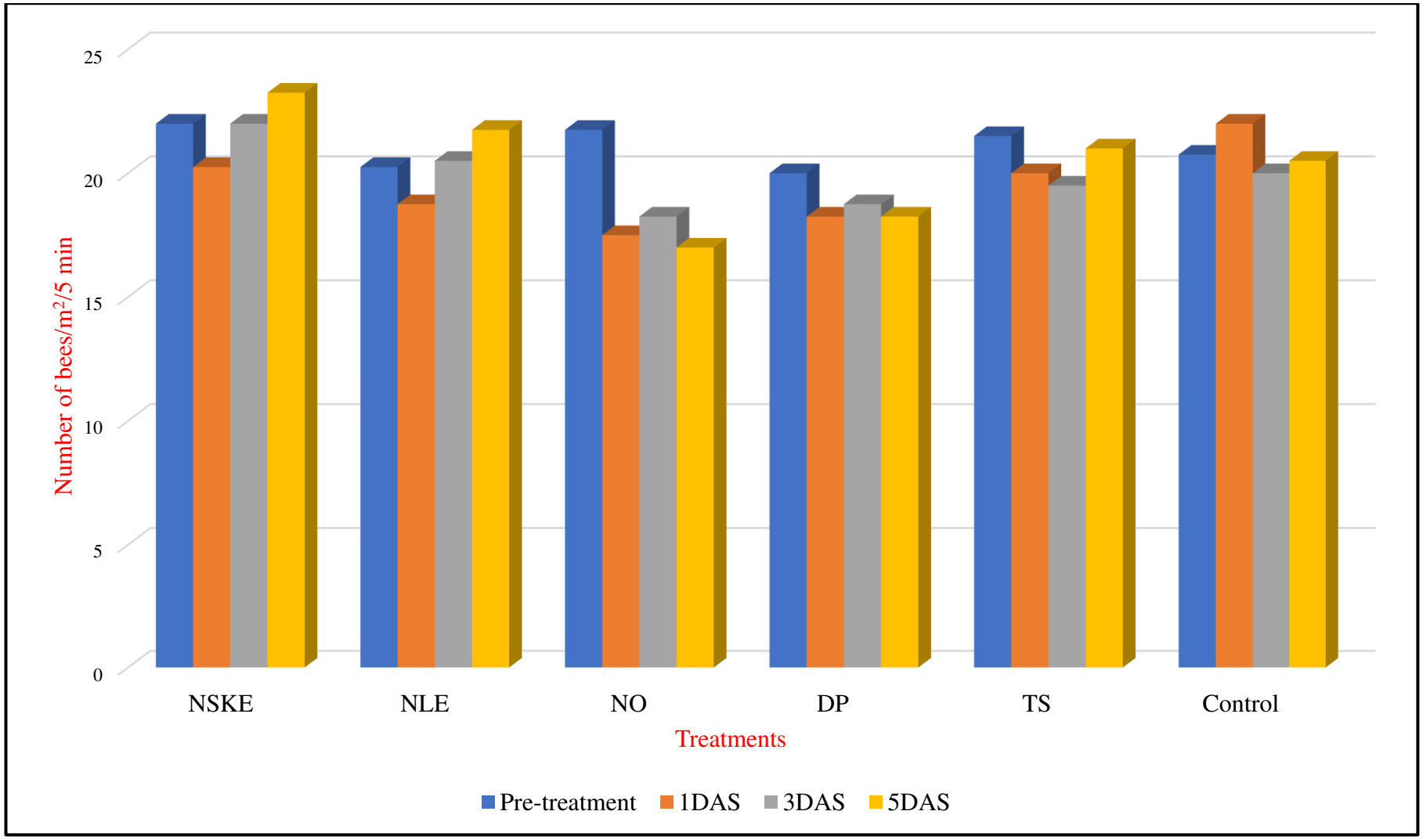


Fig. 4: Effect of botanicals on the intensity of Honey bee pollinators of pumpkin (Numbers/m^2/5 min)

Table 5. Effect of botanicals on the mean Honey bee pollinator intensity over control

Treatments	Pollinator intensity (%)		
	I day	III day	V day
***Azadirachtin* seed kernel extracts (5%)**	(-)7.95 *(21.12)	(+)9.09	(+)13.41
***Azadirachtin* leaf extracts (10%)**	(-)14.77 (20.58)	(+)2.43	(+)6.09
***Azadirachtin* oil (1%)**	(-)20.45 (29.41)	(-)8.75	(-)17.07
Dushparni (10%)	(-)17.04 (20.94)	(-)6.25	(-)10.97
Teekha sat (3%)	(-)9.09 (18.57)	(-)2.5	(+)2.43
S. Em. ±	1.43		
C. D.	4.35		

*** Figures in parenthesis are arc sine values, + indicates per cent increase in pollinator intensity and - indicates per cent decrease in pollinator intensity**

Plate 4: Pumpkin flower damaged by red pumpkin beetle

Plate 5: Pumpkin crop leaf damaged by Red pumpkin beetle

Table 6. Effect of various botanicals on Red pumpkin beetle, *Raphidopalpa foveicollis*

Treatments	Average number of Red pumpkin beetles/m^2(Days after spray)			
	Before spray	**1**	**3**	**5**
***Azadirachtin* seed kernel extracts (5%)**	2.33 *(4.50)	1.79 (2.25)	1.49 (1.50) [c]	1.31 (0.75) [c]
***Azadirachtin* leaf extracts (10%)**	2.03 (3.25)	1.92 (2.75)	1.72 (2.00) [bc]	1.57 (1.50) [bc]
***Azadirachtin* oil (1%)**	2.22 (4.00)	2.11 (3.50)	1.99 (3.00) [ab]	1.78 (2.25) [ab]
Dushparni (10%)	2.17 (3.75)	1.99 (3.00)	2.05 (3.25) [ab]	1.91 (2.75) [ab]
Teekha sat (3%)	2.36 (4.75)	2.15 (3.75)	2.05 (3.25) [ab]	1.86 (2.50) [ab]
Control	1.95 (3.00)	2.11 (3.50)	2.22 (4.00) [a]	2.28 (4.25) [a]
S. Em. ±	0.16	0.10	0.09	0.10
C. D.	N. S	N. S	0.28	0.32

***Figures in parenthesis are retransformed values and those outside are square root transformed values**

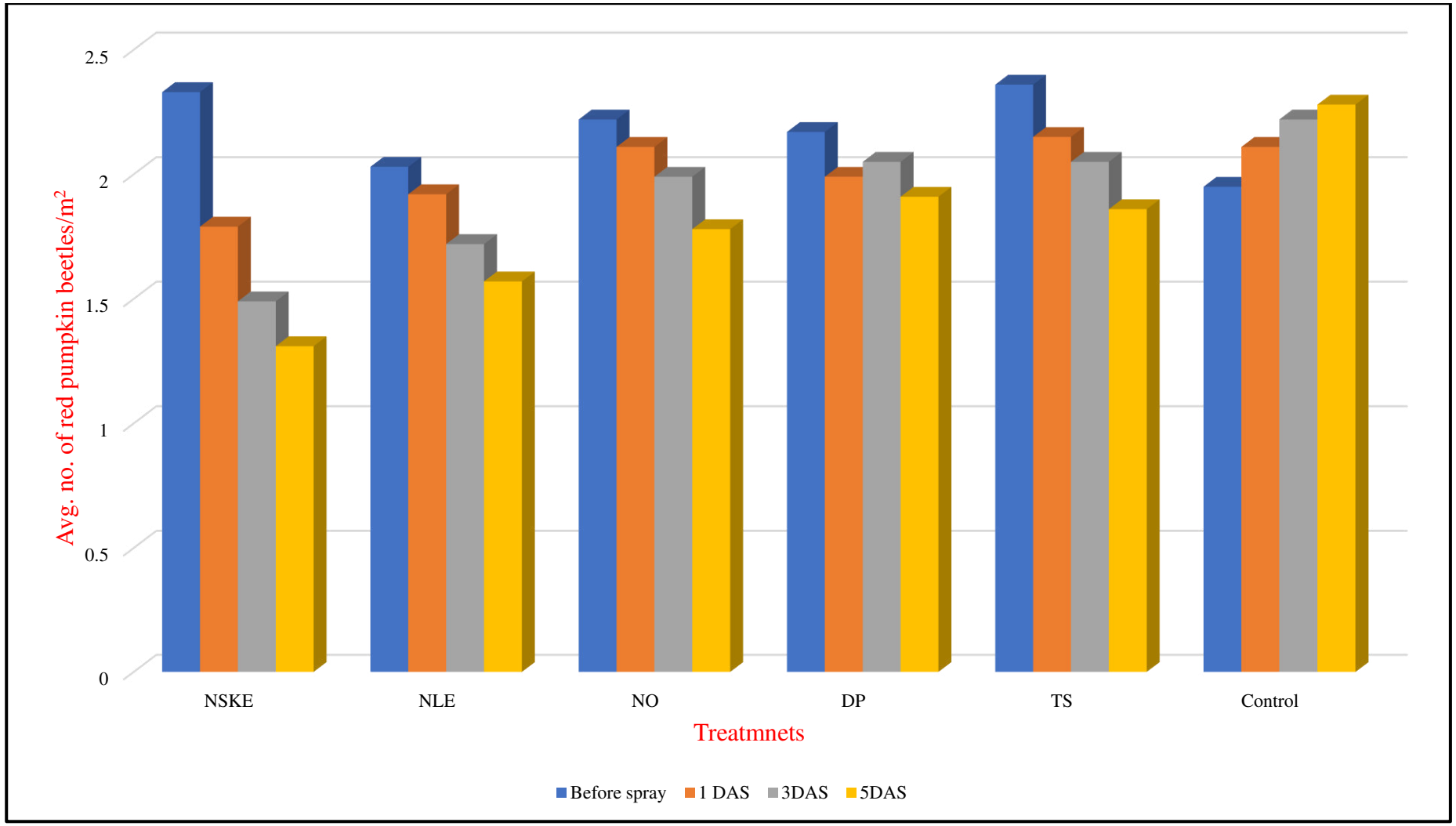


Fig. 5: Effect of various botanicals on Red pumpkin beetle, *Raphidopalpa foveicollis*

5. DISCUSSION

Results of the experiment related to diversity of insect pollinators of pumpkin, foraging activity of major insect pollinators of pumpkin, bio-efficacy of botanicals on the major insect pest of pumpkin and their side effects on insect pollinators were discussed under different heads in this chapter.

5.1 Estimating diversity of insect pollinators visiting pumpkin flowers

The flower of pumpkin attracts different insects belonging to the order Hymenoptera, Lepidoptera and Diptera. During estimation, total of 7 species were found foraging on pumpkin flowers. The most dominant species was honey bees (81.68%). Wasps, butterflies and syrphids are the pollinators other than honey bees. It contributes 17.97% to pollinators fauna. Among honey bees, the most dominant and common species was *Apis dorsata* (67.40%) followed by *A. florea* (14.28%).

The present results are in accordance with the results of Nicodema *et al.* (2009), Ali *et al.* (2014) who reported that pollination in pumpkin was mainly depends on bees. Satheesha (2010) reported that honey bees constitute 47% of the total insect pollinators. Hanh *et al.* (2014) observed 24 insect species visiting cucumber which includes 12 Hymenopterans, 6 Lepidopterans, 3 Dipterans, 2 Hemipterans and 1 Coleopteran. Balandan *et al.* (2017) reported that bees, such as *A. dorsata*, *A. cerana*, and *Trigona spp.*, were major visitors on all cucurbits. Subhakar *et al.* (2011) reported that among all insect visitors, Hymenoptera order constituted the major chunk of pollinators (88.51%) followed by Diptera (5.81%) and Lepidoptera was the least (4.68%). Dorjay *et al.* (2017) reported that honey bees are the most important pollinators which comprised more than 69% of the total flower visiting insects and Gautam and Kumar (2018) recorded 8 insect species visiting ridge gourd flowers *viz.* 5 Hymenopterans, 2 Dipterans and 1 from Odonata. The earlier results were clearly shows the dominance of Hymenopterans mainly honey bees followed by Dipterans as pollinators which are in accordance with the present results.

5.2 Study the foraging behaviour of major insect pollinators of pumpkin

The three species of honeybee's *viz.*, *Apis dorsata*, *A. cerana indica* and *A. florea* were recorded on pumpkin during *kharif* 2019.

5.2.1 Foraging behaviour of *Apis dorsata* on pumpkin

Apis dorsata activity was observed from 0600-1300 hrs with peak activity at 0900-1000 hrs. Bee activity was suddenly decreased after 1300 hr could be due to the closing of pumpkin flowers after 1100 hr of the day. The foraging behaviour of *A. dorsata* was seen throughout the flowering period. However, *A. dorsata* foraging activity was maximum on 15th day and the lowest was recorded on 1st day after five per cent flowering may be due to the less number of flowers.

The present results are in accordance with the results of Thakur and Rana (2008) who reported that the foraging activity of insect pollinators was peaked between 0900 and 1000 hr of the day. Kumar (2010) observed that the foraging activity of *A. dorsata* was peaked between 0800-1000 hrs of the day. Hanh *et al.* (2014) reported that the peak foraging activity of insect pollinators irrespective of their species was at 0800-1000 hrs of the day and Hossain *et al.* (2018) reported that the foraging activity of insect visitors was maximum at 0800-0900 hrs.

5.2.2 Foraging behviour of *Apis florea* on pumpkin

A. florea activity was observed from 0600-1400 hrs with peak activity at 0800-0900 hrs. Bee activity was suddenly decreased after 1400 hr could be due to the closing of pumpkin flowers after 1100 hr of the day. The foraging behaviour of *A. florea* was seen throughout the flowering period. However, *A. florea* foraging activity was maximum on 10th and 15th day after flower initiation. The lowest was recorded on 5th day after five per cent flowering may be due to the cloudy weather in the early morning.

The present results more or less accordance with the results of Subhakar *et al.* (2011) who reported that foraging activity of *A. florea* was maximum at 0900-1000 hrs of the day. Swaraj lakshmi (2013) reported that the peak foraging activity of *A. florea* was between 0900 and 1100 hrs. Kumar *et al.* (2012) reported that the foraging activity of Hymenopteran insects was found to be high from 0800 h to 1000 hrs of the day and Hossain *et al.* (2018) studied that the foraging activity of insect visitors on cucumber (*Cucumis sativus* L.) and observed that activity of insects was peaked at 0800-0900 hrs of the day.

5.3 Evaluation of the bio-efficacy of botanicals on the major insect pest of pumpkin and their side effects on insect pollinators

5.3.1 Side-effects of botanicals on the major insect pollinators of pumpkin

While evaluating the side-effects of botanicals on major insect pollinators of pumpkin it could be recorded that there was a decrease in insect pollinator intensity ranging from 7.95 to 20.45%. On first day after the spray of botanicals, the reduction in insect pollinators was seen in all treatments. The minimum reduction was seen in the plots treated with *Azadirachtin* seed kernel extract (5%) (-7.95%) and the maximum reduction was seen in the plots treated with *Azadirachtin* oil (1%) (-20.45%). However, the reduction in insect pollinator intensity was significant among the treatments. On third day after the spray of botanicals, the insect pollinator intensity expressed in per cent was increased in the plots treated with *Azadirachtin* seed kernel extract (5%) and *Azadirachtin* leaf extract (10%), while they decreased in the plots treated with *Azadirachtin* oil (1%), Dusparni (10%) and Teekha sat (3%). On fifth day after the spray, the maximum reduction in insect pollinator intensity was seen in the plots treated with *Azadirachtin* oil (1%) (-17.07%) and the maximum increase was seen in the plots treated with *Azadirachtin* seed kernel extract (5%) (13.41%). The plots treated with Dusparni (10%) was shown 10.97% decrease in insect pollinator intensity, whereas *Azadirachtin* leaf extract (10%) and Teekha sat (3%) was shown 6.09 and 2.43% increase in insect pollinator intensity, respectively.

The present results are in accordance with the results of Naumann (1994) who reported that there were no significant differences in the number of foraging bees collected in neem-treated, solvent-treated, or untreated plots. Singh *et al.* (2010) reported that the maximum reduction of insect pollinators (25.06%) was recorded from plots treated with *Azadirachtin* seed oil (1%) and 3 days after the pollinator percentage increased in plots treated with NSKE (5%) and *Azadirachtin* leaf extract (10%) and Dutta *et al.* (2016) reported that the Azadirachtin 1EC appeared to be the safest to coccinellid beetles (7.50/5 plants) and foraging honey bees (9.64/plot/5 min).

The literatures available show that the neem products are usually considered to be harmless to pollinators, natural enemies and other non-target organisms. This is the reason why in most of the integrated pest management (IPM) programmes neem products given a primary preference. Present study shows that NSKE is a safe

insecticide for use in the presence of honey bees. The fact that it would not repel bees or syrphids from treated. So, it suggests that it may be possible to control certain insect pests on crops during blossom time, even when the presence of honey bees is required. But not all the neem products are safe for social insects. Some botanical pesticides affect the growth and development of the social insects that carry nectar and pollen to the hives where thousands of hive mates might be affected. During these circumstances synthetic pesticides that cause quick knock-down effect are good to use which is relatively safe for social bees because only healthy bees return to the hive.

5.3.2 Effect of botanicals on the major insect pest of pumpkin

While evaluating the effect of botanicals on the major insect pest of pumpkin it could be observed that *Azadirachtin* seed kernel extract (5%) was more effective against red pumpkin beetle followed by *Azadirachtin* leaf extract (10%). The minimum number of red pumpkin beetle/m^2 was found in the plot treated with *Azadirachtin* seed kernel extract (5%) (1.31) and *Azadirachtin* leaf extract (10%) (1.57). In botanical treated plots, the maximum number of beetles/m^2 were recorded in the plots treated with Dusparni (10%) (1.91), Teekha sat (3%) (1.86) and *Azadirachtin* oil (1%) (1.78).

These findings are somewhat similar to the observations of Khan *et al.* (2015) who reported that ethanolic-extracts of *Azadirachta indica* 5% causes 76.7% repellency against *Aulocophora foveicollis* Lucas adults under laboratory condition. Neupane and Shreshta (2016) reported that the 5ml multineem/ litre of water against red pumpkin beetle (*A. foveicollis*) gave the highest reduction of beetle population (100%) followed by 4ml/litre (91.5%), 3ml/litre (63%) and 2ml/litre (37.9%), respectively. Rashid *et al.* (2016) reported that minimum population (4.31 insects/plant) and minimum per cent leaf infestation (9.1%/plant) recorded in neem (*A. indica*) treated plots and Sathua *et al.* (2017) reported that among three botanicals namely *Allium sativum* extract, *Allium cepa* extract and NSKE, NSKE 5% caused maximum mortality of 64.50%.

6. SUMMARY

Results of the investigation conducted during *kharif* 2019 at the Horticulture Farm and the Department of Entomology, Rajasthan college of Agriculture, MPUAT, Udaipur on diversity of insect pollinators of pumpkin, foraging activity of major insect pollinators of pumpkin, bio-efficacy of botanicals on the major insect pest of pumpkin and their side effects on insect pollinators are summarized below.

Total 7 species of pollinators were found foraging on pumpkin flowers. Among these 7 species, 5 species belonged to Hymenoptera which contributes 92.78% of total pollinators, one species to Diptera and one Species to Lepidoptera. The most dominant species was honey bees (81.68%). Among honey bees, the most dominant and common species was *Apis dorsata* (67.40%) followed *A. florea* (14.28%).

A. dorsata activity was observed from 0600-1300 hrs with peak activity at 0900-1000 hrs (11.75 bees/m^2/5 min). Bee activity was suddenly decreased after 1300 hr of the day. *A. dorsata* foraging activity was maximum on 15th day (5.26 bees/m^2/5 min) after flower initiation. *A. florea* activity was observed from 0600-1400 hrs with peak activity at 0800-0900 hrs (1.95 bees/m^2/5 min). Bee activity was suddenly decreased after 1400 hr of the day. *A. florea* foraging activity was maximum on 10th and 15th day which recorded 0.74 bees/m^2/5 min and 0.66 bees/m^2/5 min, respectively.

Side-effects of botanicals on major insect pollinators of pumpkin recorded that there was a decrease in insect pollinator intensity ranging from 7.95 to 20.45%. The minimum reduction was seen in the plots treated with *Azadirachtin* seed kernel extract (5%) (-7.95%) and the maximum reduction was seen in the plots treated with *Azadirachtin* oil (1%) (-20.45%). The maximum increase was seen in the plots treated with *Azadirachtin* seed kernel extract (5%) (13.41%). The plots treated with Dusparni (10%) was shown 10.97% decrease in insect pollinator intensity, whereas *Azadirachtin* leaf extract (10%) and Teekha sat (3%) was shown 6.09 and 2.43% increase in insect pollinator intensity, respectively.

Effect of botanicals on the major insect pest of pumpkin observed that *Azadirachtin* seed kernel extract (5%) was more effective against red pumpkin beetle followed by *Azadirachtin* leaf extract (10%). The minimum number of red pumpkin beetle/m^2 was found in the plot treated with *Azadirachtin* seed kernel extract (5%)

(1.31) and *Azadirachtin* leaf extract (10%) (1.57). In botanical treated plots, the maximum number of beetles/m^2 were recorded in the plots treated with Dusparni (10%) (1.91), Teekha sat (3%) (1.86) and *Azadirachtin* oil (1%) (1.78).

Further, based on the outcome of the present investigations, it could be concluded that the pumpkin attracts large number of insects as pollinators in which the honey bees were the major group. Among honey bees, *A. dorsata* play a major role. Among botanicals treated, application of neem seed kernel extract 5% for the management of red pumpkin beetle is an appropriate control measure with less health risk and also safe for social insects.

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Insect Pollinators of Pumpkin (*Cucurbita pepo* L.) and their Foraging Behaviour

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ABSTRACT

Insect Pollinators of Pumpkin (*Cucurbita pepo* L.) and their Foraging Behaviour with different objectives like diversity of insect pollinators, foraging activity of major insect pollinators, bio-efficacy of botanicals on the major insect pest of pumpkin and their side effects on insect pollinators was conducted during *kharif* 2019 at the Horticulture Farm, Rajasthan college of Agriculture, MPUAT, Udaipur.

The insect pollinators of pumpkin consist of total 7 species. Among honey bees, *Apis dorsata* proved to be the dominant one (67.40%) followed by *A. florea* (14.28%). Other hymenopteran pollinators belong to family Halictidae (7.93%) and Sphecidae (3.17%) also shown their presence. The other pollinators include Diptera and Lepidoptera as they together constitute about 6.87%.

A. dorsata activity was observed from 0600-1300 hrs with peak activity at 0900-1000 hrs. Its activity was suddenly decreased after 1300 hr could be due to the closing of pumpkin flowers after 1100 hr of the day. *A. florea* activity was observed from 0600-1400 hrs with peak activity at 0800-0900 hrs. Its activity was suddenly decreased after 1400 hr.

Side-effects of botanicals on major insect pollinators of pumpkin recorded that there was a decrease in insect pollinator intensity ranging from 7.95 to 20.45%. The minimum reduction was seen in the plots treated with *Azadirachtin* seed kernel extract (5%) (-7.95%) and the maximum reduction was seen in the plots treated with *Azadirachtin* oil (1%) (-20.45%). Effect of botanicals on the major insect pest of pumpkin observed that *Azadirachtin* seed kernel extract (5%) was more effective against red pumpkin beetle followed by *Azadirachtin* leaf extract (10%).

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कद्दू (*कुकुरबिटा पेपो* एल.) के कीट परागणकर्ता और उनके खाना ढूंटना व्यवहार कुशल

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सारांश

कद्दू (*Cucurbita pepo L.*) के कीट परागणकर्ता एवं उनके खाना ढूंढना व्यवहार कुशल के साथ विभिन्न उद्देश्यों जैसे कि कीट परागणकों की विविधता, प्रमुख कीट परागणकर्ताओं की सक्रिय गतिविधि, कद्दू के प्रमुख कीटो पर वनस्पतियों की जैव प्रभावकारिता एवं प्रमुख परागणकर्ताओं पर उनके दुष्प्रभाव को जानने के लिए वर्ष २०१९ के खरीफ मौसम में बागवानी फार्म, राजस्थान कृषि महाविद्यालय, एमपीयूएटी, उदयपुर में एक प्रयोग का अध्ययन एवं निष्पादन किया गया।

कद्दू के कीट परागणकों में कुल 7 प्रजातियां शामिल हैं. मधु मक्खियों में, एपिस डोरसाटा प्रमुख साबित हुई (६७.४०%) जिसके बाद एपिस फ्लोरिया (१४.२८%) है। अन्य हाइमेनोप्टेरान परागणकर्ता जोकि हैलिक्टिडे (७.९३%) और स्पीशीडे (३.१७%) वंश से सम्भंदित थे, ने भी अपनी उपस्थिति दर्ज की। अन्य परागणकर्ताओं में डिप्टेरा और लेपिडोप्टेरा शामिल हैं जो लगभग ६.८७% पाए गये।

एपिस डोरसॅटा की गतिविधि की निगरानी प्रातः ६.०० बजे से दोपहर ०१.०० बजे तक की गयी। जिसमे उनकी पीक गतिविधि प्रातः ९.०० से १० बजे के बीच पायी गयी। दोपहर ०१.०० बजे के बाद उनकी गतिविधि में अचानक गिरावट दर्ज की गयी जिसका प्रमुख कारण प्रातः ११.०० बजे के बाद से कद्दू के फूलो का बांध होना हो सकता है। एपिस फ्लोरिया की गतिविधि की निगरानी प्रातः ०६.०० बजे से दोपहर ०२.०० बजे तक की गयी जिसमे उनकी पीक गतिविधि प्रातः ०८:०० से ०९.०० बजे के बीच दर्ज की गयी। दोपहर ०२.०० बजे के बाद इसकी गतिविधि में अचानक कमी पायी गयी।

कद्दू के प्रमुख कीट परागणकों पर वनस्पति के दुष्प्रभावों ने दर्ज किया कि कीट परागणकर्ता की तीव्रता में ७.९५ से २०.४५ % तक की कमी थी। न्यूनतम कमी (७.९५%) उन

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क्षेत्रो में देखी गयी जिनमे नीम के बीज गिरी के अर्क (५.०%) का उपयोग किया गया था जबकि अधिकतम कमी उन क्षेत्रो में मिली जिनमे आजादिरेक्टिन तेल(१.०%) का प्रयोग किया गया। वनस्पतियो के प्रयोग से पता चला कि लाल कद्दू कीट पर नीम के बीज गिरी के अर्क (५.०%) सबसे अधिक प्रभावी था जिसके बाद दूसरा प्रभावी वानस्पतिक, नीम पत्ती का अर्क था।

APPENDIX I: ANOVA for effect of botanicals on the mean insect pollinator intensity over control

Source of variation	d.f	S.S	MSS	F cal.
Replication	3	68.309		
Treatment	5	1914.325	382.865	46.772
Error	15	122.787	8.186	
Total	23	2105.422		

APPENDIX II: ANOVA for effect of various botanicals on Red pumpkin beetle, *Raphidopalpa foveicollis*

a) Before spary

Source of variation	d.f	S.S	MSS	F cal.
Replication	3	0.630		
Treatment	5	0.521	0.104	0.952
Error	15	1.641	0.109	
Total	23	2.793		

b) 1 day after spray

Source of variation	d.f	S.S	MSS	F cal.
Replication	3	0.258		
Treatment	5	0.383	0.077	1.680
Error	15	0.683	0.046	
Total	23	1.324		

c) 3 days after spray

Source of variation	d.f	S.S	MSS	F cal.
Replication	3	0.384		
Treatment	5	1.417	0.283	7.884
Error	15	0.539	0.036	
Total	23	2.340		

d) 5 days after spray

Source of variation	d.f	S.S	MSS	F cal.
Replication	3	0.271		
Treatment	5	2.188	0.438	9.862
Error	15	0.666	0.044	
Total	23	3.125		