INSECT FAUNA ON COCONUT (*COCOS NUCIFERA* L.) SPADIX AND EFFECT OF PESTICIDES ON MAJOR POLLINATORS

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DECLARATION

I hereby declare that this thesis entitled "**Insect fauna on coconut (*Cocos nucifera* L.) spadix and effect of pesticides on major pollinators**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

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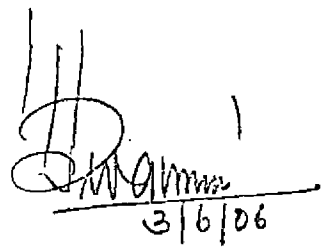

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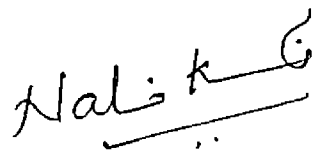

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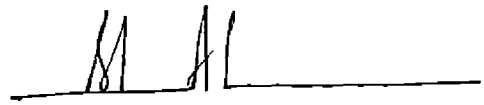

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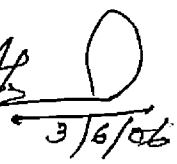

Dedicated to

My Beloved Parents

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LIST OF ABBREVIATIONS

%	Per cent
CD	Critical difference
cm	Centimetre(s)
°C	centigrade
EC	Emulsifiable concentrate
et al.	And others
Fig.	Figure
g	Gram
h	Hour
HAT	Hours After Treatment
Km/h	Kilometer per hour
ml	Millilitre
min	Minute (s)
MAT	Minutes After Treatment
spp.	Different species
viz.	namely
WDP	Water dispersible powder

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Introduction

1. INTRODUCTION

The coconut palm (*Cocos nucifera* L.) or "Kalpavriksha" is of great importance to mankind. It serves as a source of food and shelter to human being and also as raw material for industrial purposes. Therefore, it assumes a considerable importance in the national economy with the view of the income generated through foreign exchange and its vast employment potential for rural population.

The coconut palm remains in bloom throughout the year. McGregor (1976) had summarized the present knowledge on floral biology and pollination requirement of coconut. Both staminate and pistillate flowers of coconut produce nectar and the staminate flowers alone produce pollen. Coconut is an important and permanent source of pollen for honeybees. Honeybees are attracted to the flowers for both nectar and pollen collection. Thampan (1981) reported that in the centre of female flower three nectar glands are present which attract the insects and when the stigma of the female flowers is receptive a clear sweet fluid is secreted.

Satyabalan *et al.* (1968) identified bees as an important pollinating agent of coconut. Honeybee species *viz.*, *Apis cerana indica*, *A dorsata, A. mellifera*, *A. florea* and *Trigona iridipennis* tend to visit the inflorescence in large number (Suryanarayana *et al.*, 1990 and Munaan, 1997). According to Suresh *et al.* (2003), the yield of coconut was higher in bee-pollinated coconut crop.

Reports from various other countries showed that a large number of other insects are also found to be associated with the coconut palm. Hunger (1920) reported that the coconut inflorescence was visited by several species of flies and bugs. Sholdt (1966)

identified 51 species of insects on the coconut inflorescence. Several workers reported the role of ants, earwigs, flies and wasps as important pollinators in coconut (Furtado, 1924; Kidavu and Nambiar; 1925 and Davis, 1954). Being an important cash crop, a lot of plant protection measures for the management of different pests attacking the coconut inflorescence are used (KAÚ, 2003). As bees are the most efficient and primary source of pollination, a negative effect of these chemicals could occur on them.

Not much work has been carried out so far in Kerala to assess the insect species associated with coconut inflorescence as pollinators especially different species of honeybees and the impact of the commonly used insecticides and acaricides for the management of major pests of coconut, on the bees. While considering the production and productivity of coconut, both pollination by insects as well as protection of the crop from pests are equally important. Under such situation, knowledge on the insects visiting the palm, foraging activity of honeybees and to screen out safer pesticides to the pollinators from the recommended ones are of much importance. Therefore, the present study was undertaken with the following objectives;

- To document the different insect species present on the coconut inflorescence
- To find out the variations in foraging activity of different insect species
- To assess the relative safety/toxicity of different pesticides to honeybees

Review of Literature

2. REVIEW OF LITERATURE

Insects are considered as the important pollinators of coconut. Among them, honeybees play a major role. The pesticides, which are applied for the management of pests of coconut, are found to cause deleterious effects on the bees. The literature related to the foraging behavior of different insect species visiting coconut inflorescences, influence of seasonal variation on the foraging activity of these insects and the relative toxicity of pesticides on bees are reviewed hereunder.

2.1 DIFFERENT INSECT SPECIES ON VARIOUS CROPS

2.1.1 Coconut Inflorescence

A large number of different insect species have been reported to visit the coconut inflorescence either to collect pollen or nectar or both and served as pollinators in coconut and other crops.

2.1.1.1 Honey bees

According to Hunger (1920) honeybees served as agents of pollination in coconut. Pollination was chiefly carried out by insects, most importantly bees (Aldaba, 1921).

Apis mellifera

Payawal *et al.* (1986) showed that the Italian bee, *A. mellifera* visited coconut inflorescence which provided year round pollen and nectar to these bees. *A. mellifera* showed flower fidelity to the coconut palm and therefore their major pollen source

was also from these palms (Forbes and Cervancia, 1994). According to Diaz and Santana (1996), *A. mellifera* was an efficient pollinator of the coconut palm.

Suryanarayana *et al.* (1990) reported that apart from nectar, coconut is also an important and permanent source of pollen to *A. mellifera.* According to Munaan (1997), *A mellifera* showed flower fidelity to coconut palm and categorized them as outstanding pollinators of the palm. *Cocos nucifera* L. was one of the chief pollen-providing flora to *A. mellifera* (Raju, 2002 a; Nagaraja and Reddy, 2003 and Suresh *et al.*, 2003).

A. mellifera visited the coconut palm for pollen and nectar collection (Menon and Pandalai, 1958). According to Thampan (1981), coconut palm provided year round pollen to *A. mellifera.*

Apis cerana indica

Aldaba (1921) reported that one of the chief pollinator of the coconut palm is *A. cerana indica.* According to Crane *et al.* (1984), *A. cerana indica* forages on young coconut buttons that are coated with nectar.

Nehru *et al.* (1984) reported *Cocos nucifera* as a major pollen source for *A. cerana indica* in India. Suryanarayana *et al.* (1990) suggested that *A. cerana indica* visited the coconut inflorescence for both pollen and nectar collection. *A. cerana indica* followed the rule of flower fidelity to the coconut palm and the bees foraged the palm for pollen collection and therefore served as an outstanding pollinator (Munaan, 1997).

A. cerana indica is an efficient pollinator which visited the coconut inflorescence for both pollen and nectar collection (Menon and Pandalai, 1958). Thampan (1981) also opined that the Indian honeybee, *A. cerana indica* foraged for both nectar and pollen in coconut.

Trigona iridipennis

According to Ramanujam *et al.* (1993) *Cocos nucifera* served as an important nectar and pollen source to *T. iridipennis*.

2.1.1.2 Ants

Davis (1954) recognized different species of insects which included ants, that served as a cross pollinating agent in coconut. According to Sholdt (1966), the coconut inflorescences were visited by different species of ants in Hawaii.

Black ant, *Componotus compressus* played an important role in the pollination of coconut in Madras (Patel, 1938). Suresh (2002) also reported the presence of various species of ants on the coconut inflorescence in Tamil Nadu.

2.1.1.3 Flies

According to Hunger (1920), flies served as a pollinating agent in coconut. Aldaba (1921) reported that the most important pollinating agent in coconut in Philippine is house fly (*Musca domestica*) with other dipterans. The role of flies in the cross pollination of coconut was also mentioned by Davis (1954).

In India, Kidavu and Nambiar (1925) showed the importance of flies in the pollination of the coconut palm. Kumar *et al.* (1997) from Tamil Nadu, India also reported that apart from honeybees, flies also visited the coconut inflorescence. Suresh (2002) also recorded various species of flies visiting the coconut inflorescence.

2.1.1.4 Wasp

Kumar *et al.* (1997) reported that apart from honeybees, different species of wasps also visited the coconut inflorescence.

2.1.2 Other Crops

Jeong and Choi (1988) reported that honeybees formed 80.2 – 86.2 percentage of the total insect population on apple flowers. Honeybees constituted 51.4 percentage of the total insect pollinators on pear, 63.1 percentage on apple flowers and were the dominant visitors in sesamum (Lee *et al.*, 1988). Buchmann and Shipman (1990) (*Gossypium* sp.); Kozjek *et al.* (1999) (crimson clover and alfalfa); Goodman *et al.* (2001) (buck wheat cv. Manor); Stern *et al.* (2001) (apple); Ambethgan (2002) (cashew); Santana *et al.* (2002) (beans); Halagic (1999) (red clover and alfalfa); Popovic *et al.* (1993) (kiwi fruit); and Kato and Nogueira (2002) (*Cucumis melo* L.) have reported the dominance of honeybees in the respective crop systems.

Grewal and Sidhu (1978) (*Cucurbita pepo* L); Rai and Gupta (1988) (apple and pear); Grewal and Sidhu (1983) (*Cucumis melo* L); Dutta and Verma (1987) (apple); Suryanarayana *et al.* (1987) (sunflower); Naim (1996) (mustard); Patil and Virakamath (2000) (sesamum); Sihag and Chaudhary (2002) (bhindi,

tomato, brinjal and methi); Virakamath *et al.* (2002) (sunflower) and Chaudhary (2002) (mustard) have earlier reported the abundance of honeybees in the respective crop systems in India.

A. mellifera

According to Schinohara *et al.* (1987), *A. mellifera* pollinated heads gave higher number of seeds, germination percentage and oil content than control in sunflower. A close connection between *A. mellifera* and pollination of different crops in USA was described by Torchio (1990). Kozjek *et al.* (1999) showed that *A. mellifera* was the dominant insect species collected in crimson clover and alfalfa. According to Goodman *et al.* (2001), *A. mellifera* was an important pollinator of buckwheat and it constituted 83 percentage of the total insect visitors to the crop. Kato and Nogueira (2002) reported that *A. mellifera* was the most frequent flower visitor of melons.

In India Malaviya *et al.* (1999) found *A. mellifera* to be a good pollinator of several crops and concluded that it played a significant role in the pollination of berseem.. Abrol (1989) suggested that *A. mellifera* visited and helped in the pollination of several fruit and field crops. *A. mellifera* foraged for both nectar and pollen on wild cherry (Gupta *et al.*, 1990). *A. mellifera* visited the flowers of *Abelmoschus esculentus* cv. Pusa Sawani and served as an important pollinator (Tanda, 1985). Kumar and Lenin (2000) were of the view that *A. mellifera* was the

predominant flower visitor in sesamum. *A. mellifera* predominated and outnumbered all the other pollinators/insect visitors on litchi blooms (Chaudhary *et al.*, 2002).

A. cerana indica

Rubin and Cervanica (1999) reported that *A. cerana indica* was seen on the flowers of Chinese mustard and concluded that the fruit set, seed set and pod formations were higher in bee-pollinated crop than in control. The most frequent flower visitor in 71 species of woody plants, out of the 83 species observed in Hong Kong, was *A. cerana indica* (Corlett, 2001) and therefore it was concluded as the most important and efficient pollinator.

A. cerana indica visited the flowers of *Abelmoschus esculentus* cv. Pusa Sawani and served as an agent of pollination in the crop (Tanda, 1985). Abrol (1989) opined that honeybees including *A. cerana indica* were one of the most numerous flower visitors and the most important pollinator of several fruit and field crops. *A. cerana* foraged for nectar and formed one of the major flower visitors in onion (Rao and Suryanarayana, 1989). According to Gupta *et al.* (1990) *A. cerana indica* foraged for both nectar and pollen on wild cherry. Abrol (1991) reported that *A. cerana* collected both nectar and pollen from golden delicious apple variety. Honeybees, *A. cerana indica* was one of the predominant flower visitors of cardamom flowers in Haryana, India and their foraging behavior helped in the pollination of the crop (Chaudhary and Kumar, 2000).

T. iridipennis

In India, Goel and Kumar (1981) showed that *T. iridipennis* was the major pollinator of *Helianthus annuus* L. owing to its visit in large numbers during the blooming phase of the crop. Chaudhary and Kumar (2000) reported that *T. iridipennis* was one of the dominant flower visitors in cardamom and they concluded that bee pollination resulted in better quality capsules of uniform shape and bigger size.

2.1.3 Foraging Activity of Honeybees on different crops

2.1.3.1 Honeybees in Coconut

Suresh *et al.* (2003) reported that the peak period of activity by honeybees on coconut inflorescences occurred between 0900 h – 1100 h in the forenoon hours and a second peak occurred between 1600 h – 1700 h in the afternoon hours and they concluded that honeybees preferred to forage throughout the day on the coconut inflorescences.

2.1.3.2 Honeybees in Other Crops

A. mellifera

Schinohara *et al.* (1987) reported that *A. mellifera* recorded its peak activity at 1630 h in sunflower. According to Jeong and Choi (1988), foraging by bees on apple flowers started at 0900 h, reached a maximum at about 1100 h and again at 1300 h and finally ceased at about 1800 h.

In India, Sihag and Khatkar (1999b) showed that *A. mellifera* visits were low in the morning reached a peak during 1000 h – 1300 h and again declined in the evening. The highest activity of *A. mellifera* was recorded at 1000 h in sunflower (Singh *et al.*, 2000). *A. mellifera* foraged for pollen throughout the day from 0600 h onwards with two distinct peaks at 0900 h – 1000 h and 1700 h – 1800 h were recorded (Kallesha and Virakamath, 2000). Vishweshwaraiah *et al.* (2002) reported that the peak period of activity by *A. mellifera* in guava occurred during 0900 h. *A. mellifera* activity in sesamum peaked during 1000 h – 1100 h and then decreased (Yogesh *et al.*, 2003)

A. cerana indica

Rangarajan *et al.* (1974) showed that *A. cerana indica* visits were more intense during the early part of the day (between 6 am to 11 am) while during noon period (between 12 pm to 2.30 pm), the bee activity was limited. The peak period of activity by *A. cerana indica* in Nainital, India, was between 0800 h –1000 h in February - March and July - September for pollen collection while for nectar collection, it was between 1200h – 1400 h during February – April and October - November in pigeon pea (Verma, 1983). Chandran *et al.* (1983) recorded the peak period of activity of *A. cerana indica* from 0800 h –1100 h.

In Tripura, Pande and Bandyopadhyay (1985) had reported that foraging activity of *A. cerana* commenced at 0800 h and stopped after 1600 h in pigeon pea, the maximum activity being recorded between 1000 h – 1400 h. The peak period of activity was around 1000 h in case of *A. cerana indica* (Gupta *et al.*, 1990) and they

suggested that the peak pollen collection was between 0800 h – 0900 h in wild cherry. The visits made by *A. cerana* to *Mangifera indica* L. gradually increased from 0600 h to 1000 h but more number of bees visited during 0900 h – 1000 h, which was considered as its peak period of activity (Jyothi, 1994). Reddi *et al.* (1997) reported that all the foragers of *A. cerana* appear on the flowers of tamarind between 0500 h and 1900 h with more frequent visits during 0700 h – 0800 h than at other times.

T. iridipennis

Peckolt (1894) was the first to observe that *T. iridipennis* which started foraging at about 0700 h and ended at 1900 h, with a peak period occurring at 0900 h – 1000 h. According to Lazari *et al.* (1988), *Trigona* sp. and *Nanotrigona* sp. were the most important flower visitors of *Caesalpinia peltophoroides* with a peak activity between 0900 h –1300 h.

Goel and Kumar (1981) observed that the most preferred time for foraging by *Mellipona iridipennis* was during 1000 h and 1300 h on sunflower. In cardamom, *T. iridipennis* recorded the peak period of activity from 0800 h –1100 h (Chandran *et al.*, 1983). Rao and Suryanarayana (1989) reported that the peak population of *T. iridipennis* was observed at 1300 h for pollen foraging in onion.

2.2 SEASONAL OCCURRENCE OF HONEYBEES

Bisht and Pant (1968) reported that *A. cerana indica* collected pollen throughout the year and the number of pollen gatherers was highest in January and March while there was lesser activity during February, April, September and October.

Moderate to heavy rain inhibits bee flight and foraging not only because they cause reduction in atmospheric temperature but also because bees themselves are subjected to the risk of wetting, drenching or even drowning and thus the physical environment profoundly influences the life and activities of honeybees and also indirectly through nectar and pollen yields (Adlakha and Dhaliwal, 1979).

The foraging activities in honeybee colonies were greatly influenced by rainy days, high humidity and other uncomfortable weather parameters (Naim and Phadke, 1976). Pande and Bandyopadhyay (1985) reported that the honeybees foraging activity was reduced on cloudy days, low intensity of light and low temperature.

2.2.1 Effect of Weather Parameters on the Occurrence of Honeybees

Lee *et al.* (1988) reported that honeybee visits were positively correlated with temperature and light, and with humidity it was negatively correlated. The foraging activity of honeybees was correlated with solar radiation intensity but not with temperature, relative humidity or wind velocity (Jeong and Choi, 1988). Sinha and Chakrabarti (1992) have reported a close association between the insects' foraging activity and prevalent weather conditions in carrot seed crop.

Several weather components *viz.*, temperature, humidity, light, solar radiation and time of day had been reported to regulate the foraging activity of bees and other visitors (Sihag and Abrol, 1986; Abrol, 1991 and Corbet *et al.*, 1993). Temperature was positively correlated with the number of visits made by *A. cerana indica* whereas there was no significant correlation with humidity (Chand *et al.* 1994). Vicens and

Bosch (2000) showed that the visits by *A. mellifera* to apple flowers were generally influenced by weather parameters like temperature, solar radiation and wind speed and the bees were not seen foraging under strong wind or light rainy conditions. Chaudhary *et al.* (2002) have reported that maximum temperature, minimum temperature and humidity showed significant correlations with the foraging activity of different flower visiting insects.

2.3 EFFECT OF PESTICIDES ON HONEYBEES

Hafliger (1949) showed that BHC was about 200 times and parathion was 300 – 500 times more toxic to honeybees than DDT suspensions. Dimethoate was highly toxic to bees which foraged on treated turnip flowers (Palmer-Jones *et al.*, 1959). Stevenson and Walker (1974) reported that accidental poisoning of honeybees by insecticides was due to the organophosphates applied in sprays on crops during their flowering period. Carbaryl was lethal to honeybees on the day of application (Stanger and Winterlin, 1975). Loss of pollination efficiency, adult mortality and larval mortality are likely to occur as a result of dimethoate contamination of nectar (Waller *et al.*, 1979). Fiedler (1987) reported that the intake of small amounts of insecticides resulted in increased mortality and reduced consumption in honeybees.

The lab ingestion and indirect contact of some organophosphate (chlorpyriphos-methyl, dimethoate, ditalimfos and fenvalerate) were toxic to honeybees (Arzone and Patetta, 1982). Thapa and Wongsiri (1999) reported that the application of azadirachtin A and azadirachtin B had no toxic effects on honeybees

while lamda cyhalothrin and permethrin showed adverse effects when applied in the field. Sugar syrup containing as low as 0.1% azadirachtin was avoided by honeybees which suggested its repellent action in bees (Naumann *et al.*, 1994).

A. mellifera

Graves and Mackensen (1965) showed that all treatments (DDT, endrin, carbaryl and toxaphene) were toxic to the honeybee, *A. mellifera*. According to Smirle *et al.* (1984), a single sub lethal exposure of some organophosphate insecticides shortened the life span of the workers of *A. mellifera*. The pyrethroid insecticide, WL 85871, caused acute and residual toxicity to honeybees, *A. mellifera,* and was highly toxic to bees in both topical and oral administration method (Murray, 1985). Mclaren *et al.* (1987) showed that honeybee (*A. mellifera*) mortality was higher in those exposed to microencapsulated than those exposed to emulsifiable concentrate formulation of insecticides. Erickson *et al.* (1997) reported that encapsulated methyl parathion increased bee mortality and reduced total pollen collection rates in California and Philadelphia.

A. mellifera had acute toxicity to carbaryl, vamidothion, dimethoate, phosalone, phosphamidon, methyl demeton and fenitrothion when fed with poisoned nectar on cut flowers of mustard (Hameed *et al.*, 1973). All chemical treatments were toxic to *A. mellifera*, both in dry film method and oral feeding method (Prakash and Kumaraswami, 1984). Danka *et al.* (1986) showed that permethrin, carbaryl, azinphos methyl and methyl parathion were toxic to *A. mellifera*. Hundred percent kill was

observed in all systemic insecticide treatment that revealed the high toxic nature of chemicals to *A. mellifera* (Thakur and Kashyap, 1989). Brar *et al.* (1992) showed that carbaryl, endosulfan, fluvalinate and monocrotophos were all toxic to workers of *A. mellifera* when sprayed on cotton. Abrol and Kumar (2000) reported that all chemical pesticide treatments reduced the strength of brood and killed large numbers of foragers when compared to neem oil and control treatments. All the chemical insecticides were toxic to *A. mellifera* where as neem oil proved to be the safest among all treatments (Abrol and Andotra, 2000). Gowda *et al.* (2002) showed that both endosulfan and fenvalerate were moderately toxic to *A. mellifera* when fed orally whereas quinalphos and carbaryl were toxic in case of topical application method. Dimethoate was highly toxic to the eggs and larvae of *A. mellifera* resulting in its complete mortality. Toxicity of pesticides caused while foraging and also inside the hive due to presence of pesticide residues in nectar and pollen as reported by Kashyap and Kumar (2002). Mall and Rathore (2003) reported that dimethoate and quinalphos was repelling chemicals where less number of bees visited when compared to control treatments.

A. cerana indica

Kapil and Lamba (1974) reported that methyl demeton and endrin to be moderately toxic whereas malathion and phosphamidon to be toxic to *A. cerana.* Demeton methyl, carbaryl, phosphamidon and dimethoate proved highly toxic to the workers of *A. cerana indica* (Singh *et al.*, 1974). Studies on the toxicities of some

insecticide to *A. cerana indica* were carried out by Mishra and Verma (1982) in Himachal Pradesh and they found endosulfan to be the least toxic as contact poison followed by phosalone, chlorpyriphos and fenvalerate. Prakash and Kumaraswami (1984) showed that phosalone was least toxic and carbaryl was more toxic to *A. cerana indica* in topical application method. Malathion was comparatively less toxic than monocrotophos and DDVP to *A. cerana indica* (Hasan *et al.* 1986).

Dimethoate when sprayed to the fields of *Brassica chinensis*, where colonies of *A. cerana* was present, caused toxic effects on the bee population (Rana and Goyal, 1996). Vaidya and Kumar (1997) showed that the decreasing toxicity of insecticides to the foraging honeybees was in the order of phosphamidon, dimethoate, monocrotophos and endosulfan. All chemical insecticides were toxic to *A. cerana* in both oral feeding and contact method treatments (Nataraja *et al.*, 2002).

Raju (2002 b) reported that insecticides like carbaryl, dimethoate, quinalphos, were highly toxic, malathion being moderately toxic and endosulfan being non-toxic to *A. cerana*. All the insecticide treatment namely chlorpyriphos, quinalphos carbaryl, acephate, fenvalerate and endosulfan were moderately toxic to *A. cerana* when fed orally (Gowda *et al.*, 2002). Khan and Dethe (2004) found that endosulfan took the longest and imidacloprid took the shortest time for penetration into the test organism (*A. cerana indica*).

Materials and Methods

3. MATERIALS AND METHODS

Studies were undertaken to document and identify the honeybees and other insect species visiting the coconut inflorescence, to find out the foraging activities of different insect species and to assess the effect of different pesticides, recommended for the management of pests of coconut, on the bees. The experiments were conducted in the laboratory and at the Instructional Farm, College of Agriculture, Vellayani. The materials used and the methods adopted were summarized here under.

3.1 ASSESSMENT OF DIFFERENT INSECT SPECIES ON COCONUT INFLORESCENCE

Different species of insects visiting the coconut inflorescence were observed initially for five days to get a generalized view about their foraging behaviour. The coconut variety selected for the study was 'Komadan'. Five coconut palms of same age and height were selected. Flying insects which included bees, wasps, flies and moths were collected with the help of a sweep net having 20 cm, 50 cm and 30 cm as diameter of the frame, length of the cloth and length of the handle respectively. The non-flying insects *viz.*, ants, beetles and earwigs were collected using a muslin cloth bag (1.5 m x 0.5 m) with a thread at the mouth for tying. The flying insects were collected and carefully transferred into a polythene bag and tied with a rubber band. The non-flying insects were collected by carefully inserting the inflorescence into the muslin cloth bag and then the mouth end was tied by a thread. The inflorescence was then tapped gently and the insects fell inside the bag. The bag was then immediately

drawn back and the collected insects were quickly transferred to the polythene bags and tied with a rubber band. The collected insects were then brought to the laboratory, killed using chloroform and numbered. They were then pinned, labelleld and preserved for identification.

3.1.1 Assessment of Peak Time of Insect Visit

The determination of the peak time of different insects visiting the coconut inflorescence was done by following the method adopted by Kumar *et al.* (1997) with some modifications. The modifications were, the insects visiting the coconut inflorescence was recorded from 6 am to 6 pm for one day at 3 hours interval. Five coconut palms of same age and height served as five replications. The date of opening of the inflorescence was noted. On the tenth day after opening of the inflorescence, both flying and non-flying insects were collected as described in 3.1.

3.1.2 Assessment of Peak Day of Insect Visit

Male Phase

Experiment was undertaken to determine the peak day of insect activity on the coconut inflorescence during the male phase. Five coconut palms of same age and height served as five replications. The date of opening of the inflorescence was noted and the palm was marked and inflorescence tagged. Observations on the insect visiting the inflorescence were recorded for 20 consecutive days. The flying and non-flying insects were collected as described in 3.1.

Female Phase

Experiment was conducted to determine the peak day of insect activity on the coconut inflorescence during the female phase. The same set of palm selected in 3.1.2 was taken for recording observations. Observations on the insect visiting the coconut inflorescence were recorded for five consecutive days. The flying and non-flying insects were collected as described in 3.1.

3.2 DETERMINATION OF SEASONAL OCCURRENCE OF DIFFERENT INSECT SPECIES ON COCONUT INFLORESCENCE

Experiment was conducted to find out the fluctuations in the population of insects visiting the coconut inflorescence. Five coconut palms of same age and height were selected and the numbers of different species of insects (grouped into bees, ants, flies, wasps, beetles and moths) visiting the inflorescence were recorded at monthly intervals for one year. The flying and non-flying insects were collected as described in 3.1. The corresponding weather data for the period was also collected from the Agricultural Meteorology Department, College of Agriculture, Vellayani and the influence of various weather parameters on the number of insect visiting the inflorescence was worked out.

3.3 ASSESSMENT OF RELATIVE SAFETY/TOXICITY OF DIFFERENT PESTICIDES TO HONEYBEES

The insecticides evaluated for their relative toxicity to honeybees under laboratory conditions were sevin 50 WDP, hilfol 18 EC, malathion 50 EC,

quinaal – X 25 EC, hildan 35 EC, robgor 30 EC, neemazal 1 T/S and neem oil garlic emulsion 2.0 per cent. The experiments were conducted using dry film technique (Prakash and Kumaraswami, 1984).

Design – CRD, Treatments – 9, Replications – 3

T1 – carbaryl 0.1%

T2 – dicofol 0.1%

T3 – malathion 0.1%

T4 – quinalphos 0.05%

T5 – endosufan 0.05%

T6 – dimethoate 0.1%

T7 – neemazal 1.0%

T8 – neem oil garlic emulsion 2.0%

T9 - control

3.3.1 Preparation of Chemicals

0.1 per cent carbaryl

The commercial pesticide sevin 50 WDP supplied by Bayer Cropscience India Limited was used for the experiment. The solution was prepared by weighing 0.2 g sevin 50 WDP on an electronic balance and dissolving in 100 ml water.

0.1 per cent dicofol

The commercial pesticide hilfol 18.5 EC supplied by Hindustan Insecticides Limited was used for the experiment. A quantity of 0.54 ml hilfol 18.5 EC was measured in micropipette and it was then dissolved in 100 ml water.

0.1 per cent malathion

The commercial pesticide malathion 50 EC supplied by Sree Ramicides Chemicals Private Limited was used for the experiment. A quantity of 0.2 ml malathion 50 EC was measured in micropipette and it was then dissolved in 100 ml water.

0.05 percent quinalphos

The commercial pesticide quinaal – X 25 EC supplied by Sree Ramicides Chemical Private Limited was used for the experiment. A quantity of 0.2 ml quinaal – X 25 EC was measured in micropipette and it was then dissolved in 100 ml water.

0.05 per cent endosulfan

The commercial pesticide hildan 35 EC supplied by Sree Ramicides Chemical Private Limited was used for the experiment. A quantity of 0.15 ml hildan 35 EC was measured in micropipette and it was then dissolved in 100 ml water.

0.1 per cent dimethoate

The commercial pesticide robgor 30 EC supplied by Sree Ramicides Chemical Private Limited was used for the experiment. A quantity of 0.3 ml robgor 30 EC was measured in micropipette and it was then dissolved in 100 ml water.

0.004 percent azadirachtin

The commercial botanical pesticide neemazal 1 percent T/S supplied by M/s. EID Parry India Limited was used for the experiment. Azadirachtin 0.004 per cent solution

was prepared by measuring 0.4 ml neemazal 1 per cent T/S in a micropipette and dissolving in 100 ml water.

2.0 per cent neem oil garlic emulsion

Neem oil garlic emulsion 2.0 percent was prepared by taking 20 ml neem oil, 20 g garlic and 50 g soap. Soap was sliced and dissolved in 50 ml luke warm water. 20 g garlic was grounded and the extract was poured in 30 ml water. The soap solution of 50 ml was poured in 20 ml neem oil slowly and stirred vigorously. The garlic extract was mixed with the neem oil soap solution and diluted by adding 900 ml water and one litre of 2.0 percent neem oil garlic emulsion was prepared (KAU, 2003).

3.3.2 Collection of honeybees

Colonies of different species of honeybee *viz.*, *A. mellifera*, *A. cerana indica* and *Trigona iridipennis* were maintained in the experimental site. The adult worker bees were collected using sweep nets from their respective hive entrances and transferred to polythene bags. The bees were then taken to the laboratory and kept there for one hour to make them acclimatized to the laboratory conditions.

3.3.3 Assessment of Safety/Toxicity in the Laboratory

Test tube of 15 cm x 2.5 cm were washed thoroughly and dried. Using a 5 ml pipette, the already prepared insecticide solution was pipetted out and 0.5 ml of the solution was transferred per test tube. A set of ten such test tubes served as one replication and three such replications were maintained per insecticide treatment. The test tubes with insecticide solution were rotated in both ways so that the solution gets

equally coated on the inner surface. The tubes were rotated till the water was removed and a thin coat of the insecticide only remained. Care was taken to coat only the inner surface of the lower half of the test tube with the insecticide emulsion. The collected bees were kept inside a refrigerator for 2 minutes to reduce the activity. It was then taken out and immediately transferred to the insecticide treated test tubes with the help of a camel hair brush such that only one worker bee of a species was allowed per test tube. Forty percent honey solution soaked in fresh cotton roll was also kept inside the test tubes such that it remained within the top untreated half of the tube, which served as the food for the bees. The mouth of the tubes were covered with muslin cloth and tied with rubber band which provided enough aeration to the honeybees. The test tubes treated with water alone with one worker bee each served as control. Mortality counts of the treated bees were taken at regular time intervals.

3.4 Statistical Analysis

The data generated were subjected to analysis of variance and correlation studies (Panse and Sukhatme, 1985). Wherever the results were significant, the critical difference was worked out at five percent probability.

Results

4. RESULTS

4.1 OCCURRENCE OF DIFFERENT INSECT SPECIES ON COCONUT INFLORESCENCE

The results of the study conducted to document the different insect species associated with the coconut inflorescence, to find out the variations in foraging activity of different insect species and to determine the relative safety/toxicity of different pesticides to honeybees are presented hereunder;

The different insect species that were observed foraging on the coconut inflorescence during the entire study period is presented in Table 1. Of the thirty different insect species that were recorded during the period of study from March 2004 to February 2005; bees, ants, wasps, flies, beetles and moths represented 6, 9, 5, 6, 2 and 2 species respectively. Species of bees of the genera *Apis viz.*, *A. mellifera* L., *A. cerana indica* Fabr., and *A. dorsata* Fabr., along with *Trigona iridipennis* Smith, *Braunsapis* sp. belonging to the family Apidae and *Eupetersia* sp. belonging to the family Halticidae were observed during the present study. The different ant species recorded were *Solenopsis geminata* Fabr., *Myrmicaria brunnea* Saunders, *Pheidole spathulifera* Forel., *Cardiocondyla* sp., *Monomorium* sp., *Dolichoderus* sp. Jerdon, *Camponotus rufoglaucus* Jerdon, *C. sericeus* F., and *Oecophylla smaragdina* Fabr. All these ant species belonged to the family Formicidae. *Chalybion bengalense* Dahlbom, *Polistes hebraeus* Fabr., *Ropalidia variegata* Smith, *Vespa cincta* Fabr. and

Table 1. Different insect species observed on coconut inflorescence from March 2004 to February 2005.

Common name	Scientific name	Family	Order
Bees	*Apis mellifera* L.	Apidae	Hymenoptera
	Apis cerana indica Fabr.	"	"
	Apis dorsata Fabr.	"	"
	Trigona iridipennis Smith	"	"
	Braunsapis sp.	"	"
	Eupetersia sp.	Halticidae	"
Ants	*Solenopsis geminata* Fabr.	Formicidae	"
	Myrmicaria brunnea Saunders	"	"
	Pheidole spathulifera Forel.	"	"
	Cardiocondyla sp. Forel.	"	"
	Monomorium sp.	"	"
	Dolichoderus sp. Jerdon	"	"
	Camponotus rufoglaucus Jerdon	"	"
	Camponotus sericeus F.	"	"
	Oecophylla smaragdina Fabr.	"	"
Flies	*Hemipyrellia* sp.	Calliphoridae	Diptera
	Bactrocera cucurbitae Coq.	Tephritidae	"
	Bactrocera dorsalis Hendel	"	"
	Musca domestica Linn.	Muscidae	"
	Graptomyza brevirostris Weidemann	Syrphidae	"
	Sarcophaga sp.	Sarcophagidae	"
Wasps	*Chalybion bengalense* Dahlbom	Sphecidae	Hymenoptera
	Polistes hebraeus Fabr.	Vespidae	"
	Ropalidia variegata Smith	"	"
	Vespa cincta Fabr.	"	"
	Vespa sp.	"	"
Moths	*Euchromia polymena* L.	Amatidae	Lepidoptera
	Melanitis leda ismene Cramer	Satyriidae	"
Beetles	*Oxycetonia versicolor* Linn.	Cetoniidae	Coleoptera
	Oxycetonia sp.	"	"

Vespa sp. were the different wasp species found foraging on the coconut inflorescence. All the wasp species belong to the family Vespidae except *C. bengalense* which belonged to the family Sphecidae. Flies included *Hemipyrellia* sp. (Calliphoridae), *Bactrocera cucurbitae* Coq. and *B. dorsalis* Hendel (Tephritidae), *Musca domestica* Linn. (Muscidae), *Graptomyza brevirostris* Wiedemann (Syrphidae) and *Sarcophaga* sp. (Sarcophagidae). Beetles, included *Oxycetonia versicolor* Linn. and *Oxycetonia* sp. (Cetoniidae) also visited the coconut inflorescence along with the two moth species, *Euchromia polymena* L. (Amatiidae) and *Melanitis leda ismene* Cramer (Satyriidae). Among all these, Hymenoptera (bees, ants and wasps) appeared to be the largest insect order followed by Diptera (flies), Coleoptera (beetles) and Lepidoptera (moths) in the present investigation.

4.1.1 Assessment of Peak Time of Insect Activity

The population of insect visitors on coconut inflorescence was recorded at different time intervals on the 10^{th} day after opening of the spadix (male phase). The result is presented in Table 2.

The highest mean population in a day was shown by *A. cerana indica* (4.44) which was on par with the mean population recorded in *A. mellifera* (4.20), *S. geminata* (4.12) and *T. iridipennis* (4.04). When compared with the lowest mean population recorded in *Oxycetonia* sp. (0.84), significant higher mean populations were recorded in *Eupetersia* sp. (2.16), *Braunsapis* sp. (2.24),

Table 2. Foraging activity of different insect species visiting coconut inflorescence on the 10th day after opening of spadix (male phase)

Insects observed	Insect count at different time interval* (h)					
	0600	0900	1200	1500	1800	Mean
A. mellifera	3.40	8.20	2.20	4.80	2.40	4.20
A. cerana indica	3.00	7.60	2.00	5.80	3.80	4.44
T. iridipennis	2.20	4.60	5.60	2.40	5.40	4.04
Braunsapis sp.	1.40	2.40	1.20	5.20	1.00	2.24
Eupetersia sp.	1.40	2.20	1.40	4.00	1.80	2.16
S. geminata	3.80	5.40	3.40	3.80	4.20	4.12
M. brunnea	3.20	5.00	4.00	3.60	4.00	3.96
Dolichoderus sp.	3.80	3.80	3.40	3.00	4.00	3.60
C. sericeus	4.00	3.40	2.40	3.80	2.60	3.24
Hemipyrellia sp.	0.80	1.60	1.00	1.60	1.20	1.24
M. domestica	1.00	1.20	0.80	1.60	1.00	1.12
G. brevirostris	0.80	1.00	0.80	1.20	1.00	0.96
P. hebraeus	0.80	1.80	1.00	1.20	0.60	1.08
C. bengalense	1.00	1.60	1.00	1.00	1.00	1.12
Oxycetonia versicolor	0.80	1.20	0.80	1.40	1.00	1.04
Oxycetonia sp.	1.00	1.00	0.80	0.80	0.60	0.84
Mean	2.02	3.25	1.99	2.82	2.22	–

CD 0.29(Time)
CD 0.52(Insects)
CD 1.16(Interaction)
* Mean of five replications

C. sericeus (3.24), *Dolichoderus* sp. (3.60) and *M. brunnea* (3.96). Statistically similar mean populations were observed in case of *S. geminata*, *T. iridipennis* and *M. brunnea*. This was however, significantly higher than the mean population shown by *Dolichoderus* sp. and *C. sericeus*. *Dolichoderus* sp. and *C. sericeus* mean populations were statistically on par. A similar condition was recorded in *Braunsapis* sp. and *Eupetersia* sp. The mean population recorded in case of *Hemipyrellia* sp., *M. domestica*, *C. bengalense*, *P. hebraeus*, *O. versicolor*, *G. brevirostris* and *Oxycetonia* sp. showed no significant difference between them (values ranged from 1.24 to 0.84).

When the different time intervals were taken into consideration, significant higher mean population was recorded during 0900 h (3.25). The mean population recorded during 1500 h (2.82) was also significantly higher than all other time intervals. The lowest mean population was recorded during 1200 h (1.99) which was however on par with the mean population recorded during 0600 h (2.02) and 1800 h (2.22).

In case of *A. mellifera*, highly significant mean population was recorded during 0900 h (8.20). When compared with the lowest mean population recorded during 1200 h (2.20), significant higher mean populations were observed at 0600 h (3.40) and 1500 h (4.80). The mean population recorded during 1500 h (4.80) was statistically higher than the mean population recorded during 0600 h (3.40).

The lowest mean population of *A. cerana indica* was recorded at 1200 h (2.00) which was on par with the mean population at 0600 h (3.00). The mean population recorded during 0900 h (7.60) was significantly higher than all other time intervals. The mean population recorded during 1500 h (5.80) was the next significant higher population. However the mean population observed during 1800 h (3.80) and 0600 h (3.00) were statistically on par.

T. iridipennis recorded the highest mean population during 1200 h (5.60) which was statistically on par with the mean population observed during 1800 h (5.40) and 0900 h (4.60). This was however significantly higher than time mean population recorded during 1500 h (2.40) and 0600 h (2.20).

When compared with the lowest mean population of *Braunsapis* sp. recorded at 1800 h (1.00), significant higher mean populations were recorded during 1500 h (5.20). The mean population observed during 0900 h (2.40) and 0600 h (1.40) were on par with each other. A similar condition was recorded during 0600 h, 1200 h and 1800 h (values ranged from 1.40 to 1.00).

Significantly highest mean population of *Eupetersia* sp. was recorded at 1500 h (4.00). The lowest mean population was observed during 0600 h and 1200 h (1.40 each) which were statistically on par with the mean population recorded at 0900 h (2.20) and 1800 h (1.80).

In the case of ants, *S. geminata* recorded its highest mean population at 0900 h (5.40) which was significantly higher than the mean population

observed at all other time intervals. The lowest mean population was recorded during 1200 h (3.40) which was on par with the mean population observed during 1500 h, 0600 h (3.80 each) and 1800 h (4.20).

The lowest mean population of *M. brunnea* was observed at 0600 h (3.20) which was on par with the mean population observed during 1500 h (3.60), 1200 h and 1800 h (4.00 each). The highest mean population was recorded at 0900 h (5.00) which was on par with the mean population recorded during 1200 h and 1800 h.

Dolichoderus sp. recorded statistically similar mean population throughout the year. However, the highest and lowest mean populations were recorded at 1800 h (4.00) and 1500 h (3.00) respectively.

When compared with the lowest mean population of *C. sericeus* recorded at 1200 h (2.40), significant higher mean populations were observed during 1500 h (3.80) and 0600 h (4.00). The highest mean population was recorded at 0600 h, which was on par with the mean population observed during 1500 h, and 0900 h. The mean population recorded during 0900 h (3.40) and 1800 h (2.60) showed statistical difference among them.

Hemipyrellia sp. recorded statistically similar mean population during all the time intervals. The highest and lowest mean populations were however recorded at 0900 h, 1500 h (1.60 each) and 0600 h (0.80) respectively.

M. domestica also recorded statistically on par mean population during all the time intervals (values range from 0.80 to 1.60).

G. brevirostris on the other hand, recorded highest and lowest mean population during 1500 h (1.20) and 0600 h, 1200 h (0.80 each) respectively.

P. hebraeus, C. bengalense,O. versicolor and *Oxycetonia* sp. also recorded statistically similar mean population throughout the year.

When all the insects observed were taken into consideration, at 0600 h, the highest mean population was recorded in *C. sericeus* (4.00) followed by *S. geminata* and *Dolichoderus* sp. (3.80 each) which was however on par with the mean population recorded in *A. mellifera* (3.40), *M. brunnea* (3.20) and *A. cerana indica* (3.00). The lowest mean population was recorded in *Hemipyrellia* sp., *G. brevirostris*, *P. hebraeus* and *O. versicolor* (0.80 each) which was on par with the mean populations observed in *M. domestica*, *C. bengalense* and *Oxycetonia* sp. (1.00 each), *Braunsapis* sp. and *Eupetersia* sp. (1.40 each) and the later two were on par with *T. iridipennis* (2.20).

When compared with the lowest mean population, at 0900 h, recorded in *G. brevirostris* and *Oxycetonia* sp. (1.00 each), significant higher mean population were recorded in *Eupetersia* sp. (2.20), *Braunsapis* sp. (2.40), *C. sericeus* (3.40), *Dolichoderus* sp. (3.80), *T. iridipennis* (4.60), *M. brunnea* (5.00), *S. geminata* (5.40), *A. cerana indica* (7.60) and *A. mellifera* (8.20). The mean population observed in *A. mellifera* and *A. cerana indica* were on par with

each other. A similar condition was also observed between *S. geminata*, *M. brunnea* and *T. iridipennis*. Statistically similar mean populations were also recorded in *Braunsapis* sp., *Eupetersia* sp., *P. hebraeus*, *C. bengalense* and *Hemipyrellia* sp. (values range from 2.40 to 1.60).

At 1200h, significantly high mean population was observed in *T. iridipennis* (5.60). The mean population of *M. brunnea* (4.00), *S. geminata* and *Dolichoderus* sp. (3.40 each) were on par with each other. This was however, significantly higher than the mean population observed in *A. mellifera* (2.20) and *A. cerana indica* (2.00). The lowest mean population was recorded in *M. domestica*, *G. brevirostris*, *O. versicolor* and *Oxycetonia* sp. (0.80 each) which was on par with the mean population observed in *Hemipyrellia* sp., *P. hebraeus* and *C. bengalense* (1.00 each), *Braunsapis* sp. (1.20) and *Eupetersia* sp. (1.40). There was no significant difference between the mean populations recorded in *C. sericeus*, *A. mellifera* and *A. cerana indica*. A similar condition was observed in case of *Eupetersia* sp.. and *Braunsapis* sp.

The highest mean population at 1500 h was recorded in *A. cerana indica* (5.80) which was on par with the mean population recorded in *Braunsapis* sp. (5.20) and *A. mellifera* (4.80). When compared with the lowest mean population recorded in *Oxycetonia* sp. (0.80), significant higher mean populations were observed in *T. iridipennis* (2.40), *Dolichoderus* sp. (3.00), *M. brunnea* (3.60),

S. geminata (3.80), *C. sericeus* (3.80) and *Eupetersia* sp. (4.00). *T. iridipennis*, *Hemipyrellia* sp., *M. domestica* and *O. versicolor* showed non-significant mean population during this time interval.

At 1800 h, the lowest mean population was recorded in *P. hebraeus* and *Oxycetonia* sp. (0.60 each) which was on par with the mean population observed in *Braunsapis* sp., *M. domestica*, *G. brevirostris*, *C. bengalense* and *O. versicolor* (1.00 each) and *Hemipyrellia* sp. (1.20). The highest mean population was recorded in *T. iridipennis* (5.40) which was significantly higher than the mean population of all insect species observed. The next highest mean population was shown by *S. geminata* (4.20) which was statistically similar to the mean population observes in *M. brunnea* (4.00), *Dolichoderus* sp. (4.00) and *A. cerana indica* (3.80). This was however, significantly higher than the mean population observed in *C. sericeus* (2.60), *A. mellifera* (2.40) and *Eupetersia* sp. (1.80).

4.1.2 Assessment of Peak Day of Insect Activity

Male Phase

The data on the insect population recorded during the entire male phase is presented in Table 3. The highest population was recorded on the 13th day (4.30) which was however on par with the insect population recorded on the 14th (4.23), 12th (4.10) and 15th (4.06) day. The 12th and 16th day mean population with values 4.10 and 3.75 were on par with each other. The mean population of all insects on the 2nd day (1.32) was the least and significantly

Table 3. Mean population of different insects observed during male phase of the coconut inflorescence

Days	Number of insects																Mean
	Bees					Ants				Flies			Wasps		Beetles		
	Am	Aci	Ti	Bs	Es	Sg	Mb	Ds	Cs	Hs	Md	Gb	Ph	Cb	Ov	Os	
1	2.20	1.80	1.40	1.00	0.80	5.20	4.60	3.60	2.80	0.40	0.60	0.40	0.80	0.60	0.60	0.60	1.71
2	1.20	2.60	1.60	0.80	0.60	3.80	3.40	2.40	1.20	0.60	0.60	0.60	0.40	0.20	0.80	0.40	1.32
3	3.20	2.80	1.20	1.40	1.00	4.00	4.40	4.00	3.00	1.00	0.80	0.60	0.80	0.60	0.40	0.60	1.86
4	3.40	2.40	2.20	1.80	1.40	4.60	4.00	3.00	3.40	1.60	0.60	0.40	0.80	0.80	0.40	1.00	1.99
5	3.80	2.80	2.00	2.40	2.40	4.40	4.20	3.40	3.40	1.00	1.40	1.20	1.20	0.60	0.20	1.00	2.21
6	3.00	2.20	1.80	1.60	1.40	5.00	3.00	2.40	3.20	0.80	1.20	0.80	0.40	1.00	0.40	0.80	1.81
7	5.80	3.00	2.60	3.20	2.40	4.60	3.60	4.20	4.20	1.20	1.20	1.00	1.00	1.20	1.40	1.00	2.60
8	4.80	4.00	3.40	4.20	2.40	4.40	4.20	4.40	2.80	1.80	0.80	1.60	0.80	1.00	1.20	1.20	2.69
9	5.20	4.20	5.00	4.20	3.60	4.60	5.20	3.60	4.00	1.80	1.00	1.20	1.20	1.00	0.80	1.40	3.00
10	5.60	5.60	3.20	4.40	3.80	5.20	4.00	3.20	3.80	2.20	2.20	2.00	2.00	1.00	1.40	1.00	3.16
11	7.40	5.60	4.60	3.80	4.00	5.80	5.00	5.80	5.60	1.80	1.40	1.60	2.00	1.40	1.60	1.20	3.66
12	8.80	6.60	5.60	4.80	4.00	5.00	6.20	5.60	5.40	2.80	2.00	2.00	2.40	1.80	1.40	1.20	4.10
13	10.40	7.60	5.80	4.60	5.20	6.00	5.60	4.60	5.20	3.20	2.20	1.60	2.00	1.80	1.60	1.40	4.30
14	10.80	7.00	6.20	4.60	5.20	5.60	5.40	4.60	4.60	3.20	2.60	2.00	2.20	1.40	1.80	1.40	4.23
15	9.80	6.60	5.80	4.80	5.20	5.40	4.40	5.00	4.20	2.80	3.20	1.80	2.00	1.00	2.00	1.00	4.06
16	8.00	6.20	5.40	5.00	4.80	5.20	4.00	5.20	4.40	3.40	2.40	1.40	1.20	1.40	1.40	1.00	3.75
17	7.20	6.40	4.80	5.00	4.60	5.20	3.40	4.40	3.80	2.20	2.00	1.20	0.60	0.60	0.80	0.60	3.36
18	5.60	5.20	4.00	3.40	2.60	5.00	2.80	2.80	2.00	1.80	1.40	1.40	0.80	1.00	0.80	0.60	2.57
19	4.20	2.80	2.60	2.40	2.80	4.00	4.00	4.00	2.20	1.00	1.40	0.80	1.20	1.00	0.60	0.80	2.24
20	4.60	2.40	2.80	2.60	2.20	4.80	3.20	3.40	2.20	0.60	0.80	0.40	1.00	0.40	0.60	0.60	2.04
Mean	5.75	4.39	3.60	3.30	3.02	4.89	4.23	3.98	3.57	1.76	1.49	1.20	1.24	0.99	1.03	0.95	

CD 0.35(Days)
CD 0.31(Insects)
CD 1.42(Interactions)

Am	*A .mellifera*	Es	*Eupetersia* sp.	Cs	*C. sericeus*	Ph	*P. hebraeus*
Aci	*A. cerana indica*	Sg	*S. geminata*	Hs	*Hemipyrellia* sp.	Cb	*C. bengalense*
Ti	*T .iridipennis*	Mb	*M. brunnea*	Md	*M. domestica*	Ov	*O. versicolor*
Bs	*Braunsapis* sp.	Ds	*Dolichoderus* sp.	Gb	*G. brevirostris*	Os	*Oxycetonia* sp.

lower than the mean population observed on all other days. There was no significant difference in the mean population recorded on the 1st (1.71), 6th (1.81), 3rd (1.86), 4th (1.99) and 20th (2.04) day. A similar condition was noticed on the 18th (2.57), 7th (2.60) and 8th (2.69) day. This was however significantly higher than the mean population recorded on the 5th (2.21), 20th, 4th, 3rd day population. On par mean population was observed on the 17th (3.36) and 11th (3.66) day. The 10th (3.16) and 9th (3.00) day mean population also showed similar trend.

A. mellifera recorded the highest mean population (5.75) and it was significantly higher among all the insects observed in the study. *S. geminata* was the next insect which recorded higher mean population (4.89) than rest of the insect species observed. When compared with the lowest mean population (0.95) recorded in *Oxycetonia* sp., significant higher mean populations were observed in *M. domestica*, *Hemipyrellia* sp., *Eupetersia* sp., *Braunsapis* sp., *C. sericeus*, *T. iridipennis*, *Dolichoderus* sp., *M. brunnea*, *A. cerana indica*, *S. geminata* and *A. mellifera* (values ranged from 1.49 to 5.75). Statistically similar mean populations were observed in *Oxycetonia* sp., *O. versicolor*, *P. hebraeus* and *G. brevirostris* (values range from 0.95 to 1.20). Also, the mean population observed in *M. brunnea* (4.23) and *Dolichoderus* sp. (3.98) showed no statistical difference between them. A similar condition was noticed in case of *T. iridipennis* (3.60), *C. sericeus* (3.57) and *Braunsapis* sp. (3.30). There was no statistical difference between the mean population of

Hemipyrellia sp. (1.76) and *M. domestica* (1.49). The mean population of *Braunsapis* sp. (3.30) and *Eupetersia* sp. (3.02) also showed such similar trend.

The highest mean population of *A. mellifera* was recorded on the 14th day (10.80) which was on par with the mean population recorded on the 13th day (10.40) and 15th day (9.80). The mean population observed on the 12th day (8.80), 16th day (8.00) and 11th day (7.40) showed no statistical difference among them and was significantly higher than the mean population observed on the 7th (5.80), 18th (5.60), 10th (5.60), 9th (5.20), 8th (4.80) and 20th (4.60) day. The mean population recorded on the 17th (7.20) and 7th (5.80) day were on par with each other. Similar observations were made on the 20th, 19th, 5th, 4th and 3rd day (values ranged from 4.60 to 3.20). Similarly, the mean population recorded on the 4th, 3rd, 6th, and 1st day were also on par with each other (values ranged from 3.40 to 2.20). The lowest mean population was recorded on the 2nd day (1.20) which was on par with the mean population on the 1st day (2.20).

A. cerana indica recorded its lowest mean population on the 1st day (1.80) which was on par with the mean population observed on the 6th (2.20), 20th (2.40), 4th (2.40), 2nd (2.60) ,19th (2.80), 5th (2.80), 3rd (2.80) and 7th (3.00). The 9th (4.20), 18th (5.20), 11th (5.60) and 10th (5.60) day mean population were statistically on par. A similar condition was observed between the 18th, 11th , 10th, 16th, 17th, 15th and 12th day mean population (values ranged from 5.20 to 6.60). The highest mean population was recorded on the 13th (7.60) day which

was on par with the mean population observed on the 14th (7.00), 12th (6.60), 15th (6.60), 17th (6.40) and 16th (6.20) day mean population.

When compared with the lowest mean population of *T. iridipennis* recorded on the 3rd day (1.20) which was on par with the mean population on the 1st (1.40), 2nd (1.60), 6th (1.80), 5th (2.00) 4th (2.20), 19th (2.60) and 7th day (2.60), significant higher mean populations were recorded on the 18th (4.00), 11th (4.60), 17th (4.80), 9th (5.00), 16th (5.40), 12th (5.60), 15th (5.80), 13th (5.80) and 14th (6.20) day. The highest mean population was recorded on the 14th day (6.20) which was on par with the mean population observed on the 13th, 15th, 12th, 16th, and 9th day population (values range from 5.80 to 5.00).

Braunsapis sp. recorded its highest mean population on the 16th and 17th day (5.00 each) which was on par with mean population recorded on the 15th and 12th day (4.80 each), 13th and 14th day (4.60 each), 10th (4.40), 8th and 9th (4.20 each). Statistically similar mean populations were observed on the 13th, 14th, 10th, 8th, 9th, 11th, 18th and 7th day (values ranged from 4.60 to 3.20). Similar situation was observed on the 4th, 18th, 7th, 20th, 5th and 19th day (values range from 1.80 to 2.40). The lowest mean population was recorded on the 2nd day (0.80) which was on par with the mean populations on the 1st (1.00), 3rd (1.40), 6th (1.60) and 4th (1.80) day of the male phase.

Statistically similar mean population of *Eupetersia* sp. was recorded on the 13th, 14th, 15th (5.20 each), 16th (4.80), 17th (4.60) 11th and 12th (4.00 each)

and 10th (3.80) day. The lowest mean population was recorded on the 2nd day (0.60) which was on par with the 1st (0.80), 3rd (1.00), 6th and 4th (1.40 each) day population. There was no significant difference between the mean population observed on the 10th, 9th, 19th, 18th, 5th, 7th and 8th day (values ranged from 3.80 to 2.40).

S. geminata recorded its highest mean population on the 13th day (6.00) which was on par with the mean population recorded on the 11th (5.80), 14th (5.60), 15th (5.40), 1st, 10th, 16th, 17th (5.20 each), 6th, 12th ,18th (5.00 each), 20th (4.80), 4th, 7th and 9th (4.60 each) day. The lowest mean population was recorded on the 2nd day (3.80), which was on par with the mean population recorded on the 19th, 3rd, 8th, 5th, 9th, 7th, 4th, 20th, 18th, 12th, 6th, 17th, 16th, 10th, and 1st day (values ranged from 4.00 to 5.20).

The highest mean population of *M. brunnea* was recorded on the 12th day (6.20) which was statistically similar to the mean population observed on the 13th (5.60), 14th (5.40), 9th (5.20) and 11th (5.00) day population. The mean populations observed on the 3rd, 15th and 1st day were on par with each other (values range from 4.40 to 4.60). The lowest mean population was recorded on the 18th day (2.80) which was on par with the mean population observed on the 6th (3.00), 20th (3.20), 17th, 2nd (3.40 each), 7th (3.60), 19th , 16th , 10th , 4th (4.00 each) 8th and 5th (4.20 each) day.

The lowest and highest mean population of *Dolichoderus* sp. were recorded on the 2nd and 6th (2.40 each) and 11th (5.80) day respectively. The highest mean population was on par with the 12th (5.60) and 16th (5.20) day observations. A similar condition was also noticed between the 18th, 20th, 10th and 4th day observations (values ranged from 3.40 to2.80).

C. sericeus recorded the highest mean population on the 11th day (5.60) which was on par with the mean population recorded on the 12th (5.40), 13th (5.20), 14th (4.60) and 16th (4.40) day. Statistically similar mean populations were recorded between the 15th, 7th, 9th, 10th, 17th, 4th, 5th, 6th, 3rd, 8th and 1st day (values ranged from 4.20 to 2.80). The lowest mean population was recorded on the 2nd day (1.20) which was on par with the mean population recorded on the 18th (2.00), 20th (2.20) and 19th (2.20) day.

Considering the fly species, there was no significant difference between the mean populations of *Hemipyrellia* sp. recorded on the 10th, 12th, 15th, 13th, 14th and 16th day values ranged from 2.20 to 3.40). However the highest and lowest mean populations were recorded on the 16th (2.40) and 1st (0.40) day respectively.

M. domestica also showed little differences among its mean population throughout the study period. Statistically similar mean populations were recorded on the 14th, 16th, 13th, 10th, 12th and 17th day (values ranged from 2.60

to 2.00). The lowest and highest mean population was recorded on the 1st , 2nd and 4th (0.60 each) and 15th (3.20) day respectively.

The highest mean population of 2.00 on the 10th , 12th and 14th day and the lowest mean population of 0.40 on the 1st, 4th and 20th day were observed in *G. brevirostris*. Also, the highest mean population and the lowest mean population of *P. hebraeus* was recorded on the 12th (2.40) and 2nd and 6th (0.40).

In case of *C. bengalense*, the highest mean population (1.80 each) was recorded on the 12th and 13th day of observation. The mean population ranged from 0.20 to 1.40 during the other days.

O. versicolor recorded its lowest mean population on the 5th day (0.20) and the highest mean population on the 15th day (2.00) whereas *Oxycetonia* sp. recorded statistically similar mean populations throughout the observation days.

On day one, the maximum mean population was recorded in *S. geminata* (5.20) which was on par with the mean population observed in *M. brunnea* (4.60). The lowest mean population on the first day was observed in *Hemipyrellia* sp. (0.40) and *G. brevirostris* (0.40) which was on par with the mean populations recorded in case of *A. cerana indica* (1.80), *T. iridipennis* (1.40), *Braunsapis* sp. (1.00), *P. hebraeus* (0.80), *Eupetersia* sp. (0.80), *M. domestica* , *Oxycetonia* sp., *O. versicolor* and *C. bengalense* (0.60 each).

The highest mean population among all insects observed on the second day was also shown by *S. geminata* (3.80) which was on par with the mean population recorded in *M. brunnea* (3.40) and *A. cerana indica* (2.60). There were no significant difference between the mean population observed in *T. iridipennis*, *A. mellifera*, *C. sericeus*, *Braunsapis* sp., *O. versicolor*, *Eupetersia* sp., *Hemipyrellia* sp., *M. domestica*, *G. brevirostris*, *P. hebraeus*, *Oxycetonia* sp., and *C. bengalense* (values ranged from 1.60 to 0.20).

The lowest mean population on the third day was recorded in *O. versicolor* (0.40) which was on par with the mean population observed in *C. bengalense*, *Oxycetonia* sp., *G. brevirostris*, *P. hebraeus*, *M. domestica*, *Hemipyrellia* sp., *Eupetersia* sp., *T. iridipennis* and *Braunsapis* sp. (values ranged from 0.60 to 1.40). The highest mean population was observed in *M. brunnea* (4.40) which was on par with the mean population recorded in *Dolichoderus* sp. (4.00), *S. geminata* (4.00), *A. mellifera* (3.20) and *C. sericeus* (3.00).

There were no significant difference among the mean population observed on the fourth day between *A. cerana indica* (2.40), *T. iridipennis* (2.20), *Braunsapis* sp. (1.80), *Hemipyrellia* sp. (1.60) and *Eupetersia* sp. (1.40). The lowest and highest mean population was recorded in *S. geminata* (4.60) and *O. versicolor* (0.40) respectively.

When compared with the lowest mean population observed in *O. versicolor* (0.20) on the fifth day, significant higher mean populations were recorded in *T. iridipennis* (2.00), *Braunsapis* sp. (2.40), *Eupetersia* sp. (2.40), *A. cerana indica* (2.80), *C. sericeus* (3.4), *Dolichoderus* sp. (3.40), *A. mellifera* (3.80), *M. brunnea* (4.20) and *S. geminata* (4.40).

Highly significant mean population than all the other observed insects was recorded in case of *S. geminata* (5.00) on the sixth day of the male phase. *O. versicolor* and *P. hebraeus* recorded the lowest mean population (0.40) which were on par with the mean population recorded in *Hemipyrellia* sp., *G. brevirostris, Oxycetonia* sp., *C. bengalense, M. domestica, Eupetersia* sp., *Braunsapis* sp. and *T. iridipennis* (values ranged from 0.80 to 1.80).

A. mellifera (5.80) and *S. geminata* (4.60) recorded higher and on par mean population on the seventh day. The lowest mean population was observed in *Oxycetonia* sp., *P. hebraeus, G. brevirostris* (1.00 each) which was on par with the mean population recorded in *C. bengalense, M. domestica, Hemipyrellia* sp. (1.20 each), *O. versicolor* (1.40) and *Eupetersia* sp. (2.40).

The eighth day mean population showed that *A. mellifera* (4.80), *S. geminata* (4.40), *Dolichoderus* sp. (4.40), *Braunsapis* sp. (4.20), *M. brunnea* (4.20), *A. cerana indica* (4.00) and *T. iridipennis* (3.40) recorded statistically on par population. The highest mean population was recorded in *A. mellifera*

while the lowest mean population was recorded in *P. hebraeus* and *M. domestica* (0.80) each.

On the ninth day, the lowest mean population was observed in *O. versicolor* (0.80) which showed no significant difference from the mean population recorded in *C. bengalense* (1.00), *M. domestica* (1.00), and *P. hebraeus* (1.20), *G. brevirostris* (1.20), *Oxycetonia* sp. (1.40) and *Hemipyrellia* sp. (1.80). There were no statistical difference between the mean population observed in *T. iridipennis*, *S. geminata*, *A. cerana indica*, *Braunsapis* sp., *C. sericeus*, *Eupetersia* sp. and *Dolichoderus* sp. (values ranged from 5.00 to 3.60). The highest mean population was recorded in *A. mellifera* (5.20).

A. mellifera (5.60), *A. cerana indica* (5.60) and *S. geminata* (5.20) recorded higher and on par mean population on the tenth day of the male phase. Non-significant mean populations were observed in *Dolichoderus* sp., *T. iridipennis*, *Hemipyrellia* sp. (3.20 each), *M. domestica* (2.20), *G. brevirostris* and *P. hebraeus* (2.00 each). The least mean population was recorded in *Oxycetonia* sp. and *C. bengalense* (1.00 each), which was on par with *O. versicolor*, *P. hebraeus*, *G. brevirostris*, *M. domestica*, and *Hemipyrellia* sp. (values ranged from 1.40 to 2.20).

The mean population recorded in *A. mellifera* on the eleventh day (7.40) was significantly higher than the mean populations observed in rest of the

insects observed. When compared with the lowest mean population recorded in *Oxycetonia* sp. (1.20), significant higher mean populations were recorded in *Braunsapis* sp., *Eupetersia* sp., *T. iridipennis*, *M. brunnea*, *C. sericeus*, *A. cerana indica*, *Dolichoderus* sp., *S. geminata* and *A. mellifera* (values ranged from 3.80 to 7.40).

The lowest mean population on the twelfth day was recorded in *Oxycetonia* sp. (1.20) which was on par with the mean population observed in *O. versicolor*, *C. bengalense*, *G. brevirostris*, *M. domestica* and *P. hebraeus* (values ranged from 1.40 to 2.40). *A. mellifera* recorded significantly highest mean population (8.80) from all the other insect species observed.

Significantly highest mean population was observed in *A. mellifera* (10.40) on the thirteenth day when compared to the mean population of all other insect species recorded. The next higher mean population was recorded in *A. cerana indica* (7.60). There was no statistical difference between the mean population recorded in *S. geminata* (6.00), *T. iridipennis* (5.80), *M. brunnea* (5.60), *Eupetersia* sp. (5.20), *C. sericeus* (5.20), *Braunsapis* sp. (4.60) and *Dolichoderus* sp. (4.60). The lowest mean population was recorded in *Oxycetonia* sp. (1.40).

Fourteenth day observations showed that significantly highest mean population was recorded in *A. mellifera* (10.80) than the mean population recorded in all the other insect species observed. The least mean population was

recorded in *Oxycetonia* sp. (1.40) which was on par with the mean population recorded in *C. bengalense*, *O. versicolor*, *G. brevirostris*, *P. hebraeus* and *M. domestica* (values ranged from 1.40 to 2.60).

The lowest mean population on the fifteenth day was observed in *Oxycetonia* sp. and *C. bengalense* (1.00 each). The highest mean population was recorded in *A. mellifera* (9.80) which was statistically superior to the mean population observed in all the other insect species. There were no significant differences between the mean population recorded in *S. geminata*, *Eupetersia* sp., *Dolichoderus* sp., *Braunsapis* sp., *M. brunnea* and *C. sericeus* (values ranged from 5.40 to 4.20).

Statistically similar mean populations were recorded in *T. iridipennis* (5.40), *S. geminata* (5.20), *Dolichoderus* sp. (5.20), *Braunsapis* sp. (5.00), *Eupetersia* sp. (4.80), *C. sericeus* (4.40) and *M. brunnea* (4.00) on the sixteenth day. *A. mellifera* recorded the highest mean population (8.00) which was significantly higher than the mean population recorded in all the other insects.

A. mellifera recorded the highest mean population (7.20) on the seventeenth day of the male phase which was on par with the mean population observed in *A. cerana indica* (6.40). The lowest mean population was recorded in *P. hebraeus*, *C. bengalense* and *Oxycetonia* sp. (0.60 each).

The highest mean population on the eighteenth day was recorded by *A. mellifera* (5.60) which was on par with the mean population recorded in *A. cerana indica* (5.20) and *S. geminata* (5.00). The lowest mean population was recorded by *Oxycetonia* sp. (0.60) which was statistically similar to the mean population observed in *O. versicolor. P. hebraeus, C. bengalense, G. brevirostris, M. domestica, Hemipyrellia* sp. and *C. sericeus* (values ranged from 0.80 to 2.00).

Nineteenth day recorded statistically on par mean population in *A. mellifera* (4.20), *S. geminata* (4.00), *M. brunnea* (4.00), *Dolichoderus* sp. (4.00), *A. cerana indica* (2.80) and *Eupetersia* sp. (2.80). *O. versicolor* recorded the lowest mean population (0.60) which was on par with the mean populations observed in *Oxycetonia* sp., *G. brevirostris, C. bengalense, Hemipyrellia* sp., *P. hebraeus* and *M. domestica* (values ranged from 0.80 to 1.40).

The last day of the male phase of the coconut inflorescence recorded highest mean population of *S. geminata* (4.80) which was on par with the mean population recorded in *A. mellifera* (4.60) and *Dolichoderus* sp. (3.40). There was no significant difference between the mean population observed in *Dolichoderus* sp., *M. brunnea, T. iridipennis, Braunsapis* sp. and *A. cerana indica* (values ranged from 3.40 to 2.40). The lowest mean population was recorded in *C. bengalense* and *G. brevirostris* (0.40 each) which was on par

with the mean population recorded in *Oxycetonia* sp., *O. versicolor*, *Hemipyrellia* sp., *M. domestica* and *P. hebraeus* (values ranged from 0.60 to 1.00).

Female Phase

The mean population of all insects observed, during the female phase (Table 4), on the 2nd day (3.63) was significantly higher than the mean population recorded on all other days. The next higher mean population was observed on the 3rd day (3.19). The lowest mean population was observed on the 1st day (2.51) which was on par with the mean population recorded on the 5th day (2.60) and 4th day (2.74).

Among all the insects observed, *A. mellifera* and *S. geminata* recorded the highest mean population during the entire female phase (5.08 each). The mean population recorded by *M. brunnea* (4.80) and *A. cerana indica* (4.44) showed no significant difference between them. A similar condition was observed between *A. cerana indica*, *Dolichoderus* sp. (4.20) and *C. sericeus* (3.96). This was however significantly higher than the mean population observed in case of *T. iridipennis* (3.20), *Eupetersia* sp. (2.20), *Braunsapis* sp. (2.08), *M. domestica* (1.28), *Hemipyrellia* sp. (1.29), *C. bengalense* (1.24), *P. hebraeus* (1.20) and *G. brevirostris* (1.08).

First day of the female phase recorded highest population of *S. geminata* (4.80) which was on par with the mean populations observed in *M. brunnea*

Table 4. Mean population of different insects observed during female phase of the coconut inflorescence

Days	Number of insects														Mean
	Bees					Ants				Flies			Wasps		
	Am	Aci	Ti	Bs	Es	Sg	Mb	Ds	Cs	Hs	Md	Gb	Ph	Cb	
1	3.80	3.20	2.80	1.80	2.00	4.80	4.20	4.00	3.40	1.20	1.20	1.00	0.80	1.00	2.51
2	7.80	6.60	5.40	2.60	2.40	5.40	5.20	4.20	3.80	1.80	1.40	1.20	1.60	1.40	3.63
3	5.60	5.00	3.80	2.20	2.60	5.60	5.00	4.40	3.80	1.20	1.60	1.00	1.40	1.40	3.19
4	4.40	4.00	2.00	2.00	1.60	5.20	5.00	4.00	4.60	1.00	1.20	1.00	1.20	1.20	2.74
5	3.80	3.40	2.00	1.80	2.40	4.40	4.60	4.40	4.20	1.00	1.00	1.20	1.00	1.20	2.60
Mean	5.08	4.44	3.20	2.08	2.20	5.08	4.80	4.20	3.96	1.29	1.28	1.08	1.20	1.24	

CD 0.35(Days)
CD 0.58(Insects)
CD 1.32(Interactions)

Am	*A. mellifera*	Es	*Eupetersia* sp.	Cs	*C. sericeus*	Ph	*P. hebraeus*
Aci	*A. cerana indica*	Sg	*S. geminata*	Hs	*Hemipyrellia* sp.	Cb	*C. bengalense*
Ti	*T. iridipennis*	Mb	*M. brunnea*	Md	*M. domestica*		
Bs	*Braunsapis* sp.	Ds	*Dolichoderus* sp.	Gb	*G. brevirostris*		

(4.20), *Dolichoderus* sp. (4.00) and *A. mellifera* (3.8). The mean population of *C. sericeus* (3.80) was on par with the mean population of *Dolichoderus* sp. (4.20) during the second day. The lowest mean population was recorded in *P. hebraeus* (0.80) which was on par with the mean population observed in *G. brevirostris*, *C. bengalense* (1.00 each), *Hemipyrellia* sp., *M. domestica* (1.20 each), *Braunsapis* sp. (1.80) and *Eupetersia* sp. (2.00).

Statistically similar mean populations were recorded in *A. mellifera* (7.80) and *A. cerana indica* (6.60) on the second day. Also, there were no significant differences between the mean population observed in *T. iridipennis*, *S. geminata* (5.40 each), *M. brunnea* (5.20) and *Dolichoderus* sp. (4.20). The mean population of *C. sericeus* (3.40), *A. cerana indica* (3.20) and *T. iridipennis* (2.80) were on par with each other. The least mean population was recorded in *G. brevirostris* (1.20) which was on par with the mean population recorded in *M. domestica, C. bengalense* (1.40 each), *P. hebraeus* (1.60), *Hemipyrellia* sp. (1.80) and *Eupetersia* sp. (2.40).

On par mean populations were recorded in *T. iridipennis* and *C. sericeus* (3.80 each) and *Eupetersia* sp. (2.60) on the third day. Statistically similar mean population was observed in G. brevirostris, Hemipyrellia sp., P. hebraeus, C. bengalense, M. domestica and Braunsapis sp. (values ranged from 1.00 to 2.20). The highest mean population was recorded in *A. mellifera* and

S. geminata (5.60 each) which was on par with the mean population observed in *A. cerana indica*, *M. brunnea* (5.00each) and *Dolichoderus* sp. (4.40).

S. geminata (5.20), *M. brunnea* (5.00), *C. sericeus* (4.60), *A. mellifera* (4.40), *A. cerana indica* (4.00) and *Dolichoderus* sp. (4.00) were the mean populations observed on the fourth day of the female phase, which were on par with one another. The mean population recorded in *Hemipyrellia* sp., *G. brevirostris, M. domestica, P. hebraeus, C. bengalense, Eupetersia sp., T. iridipennis* and *Braunsapis* sp. were statistically similar (values ranged from 1.00 to 2.00)

Fifth day results showed that the highest mean population was recorded in *M. brunnea* (4.60) which was on par with the mean population of *S. geminata* (4.40), *Dolichoderus* sp. (4.40), *C. sericeus* (4.20), *A. mellifera* (3.80) and *A. cerana indica* (3.40). The lowest mean populations were observed in *Hemipyrellia* sp., *M. domestica* and *P. hebraeus* (1.00 each) which were statistically on par with the mean population recorded in *C. bengalense, G. brevirostris* (1.20 each), *Braunsapis* sp. (1.80) and *T. iridipennis* (2.00).

A. mellifera recorded its highest mean population on the 2nd day (7.80) which was significantly higher than the population on all the other days observed. The lowest mean population was recorded on the 1st and 5th day (3.80 each).

Similarly, *A. cerana indica* also recorded its highest mean population on the 2nd day (6.60) which was significantly higher than the population recorded on all other days. The lowest mean population was observed on the 1st day (3.20) which was statistically similar to the mean population recorded on the 5th (3.40) and 4th (4.00) day.

Significantly higher mean populations of *T. iridipennis* was observed on the 2nd day (5.40) when compared to the mean population recorded on the 4th, 5th (2.00 each), 1st (2.80) and 3rd (3.80) days.

All the other species observed *viz.*, *Braunsapis* sp., *Eupetersia* sp., *S. geminata*, *M. brunnea*, *Dolichoderus* sp., *C. sericeus*, *Hemipyrellia* sp., *M. domestica*, *G. brevirostris*, *P. hebraeus* and *C. bengalense* recorded statistically similar populations throughout the entire period of the female phase.

4.2 OCCURRENCE OF DIFFERENT INSECT SPECIES ON COCONUT INFLORESCENCE

The data on the studies of the occurrence of various insect species on the coconut inflorescence for a period of one year are presented in Table 5 to Table 9.

Bees

A. mellifera recorded its highest mean population (Table 5) in the months of April and February (9.80 each) which was on par with the mean population

Table 5. Mean population of various species of bees observed on the coconut inflorescence over a period of one year

Months	Number of bees					
	B1	B2	B3	B4	B5	B6
March '04	8.40 (2.88)	7.40 (2.72)	4.60 (2.12)	3.00 (1.72)	2.20 (1.48)	2.00 (1.39)
April	9.80 (3.12)	9.60 (3.09)	3.60 (1.88)	3.00 (1.71)	4.00 (1.98)	1.00 (1.00)
May	5.40 (2.29)	4.20 (2.03)	2.80 (1.66)	3.00 (1.72)	2.00 (1.37)	1.00 (1.00)
June	4.40 (2.06)	3.60 (1.89)	3.40 (1.80)	2.60 (1.56)	2.40 (1.51)	1.40 (1.17)
July	6.20 (2.49)	4.40 (2.08)	2.60 (1.59)	1.80 (1.31)	2.40 (1.54)	1.20 (1.08)
August	6.80 (2.61)	4.40 (2.06)	2.60 (1.60)	2.20 (1.48)	2.40 (1.54)	1.20 (1.08)
September	3.20 (1.76)	4.00 (1.99)	2.20 (1.48)	1.80 (1.33)	2.20 (1.48)	1.00 (1.00)
October	4.20 (2.03)	2.80 (1.66)	2.00 (1.41)	1.60 (1.25)	3.20 (1.70)	2.00 (1.41)
November	4.00 (1.97)	3.80 (1.93)	3.20 (1.76)	2.20 (1.48)	1.60 (1.25)	1.20 (1.08)
December	5.80 (2.37)	5.40 (2.27)	6.00 (2.42)	2.40 (1.54)	2.60 (1.60)	1.00 (1.00)
January '05	9.00 (2.99)	7.00 (2.63)	6.20 (2.49)	3.40 (1.82)	3.60 (1.87)	1.80 (1.31)
February	9.80 (3.12)	7.80 (2.78)	4.80 (2.21)	2.20 (1.46)	2.40 (1.54)	3.40 (1.82)
CD	(0.42)	(0.39)	(0.38)	(0.39)	(0.39)	(0.24)

B1: *A.mellifera*, B2: *A. cerana indica*, B3: *A. dorsata*, B4: *T. iridipennis*,
B5: *Braunsapis* sp., B6: *Eupetersia* sp.
Transformed values are in parenthesis

recorded in January (9.00) and March (8.40). The mean population recorded during August, July, December and May was on par with each other (values ranged from 6.80 to 5.40). A similar trend was observed during December, May, June, October and November (values ranged from 5.80 to 4.00). The lowest mean population was recorded in September (3.20) which was on par with the mean populations recorded during November (4.00), October (4.20) and June (4.40).

The highest mean population of *A. cerana indica* was recorded during the month of April (9.60) which was on par with the mean population recorded in February (7.80) and March (7.40). The mean population recorded in January (7.00) was statistically on par with the mean population recorded during December (5.40). A similar condition was observed during the months of December, July, August, May, September, November and June (values ranged from 5.40 to 3.60). The least mean population was recorded in the month of October (2.80).

A. dorsata recorded its lowest mean population in the month of October (2.00) which was on par with the mean population during September (2.20), July (2.60), August (2.60), May (2.80) and November (3.20). When compared with the lowest mean population recorded in the month of October, significant higher mean populations were recorded during the months of June (3.40), April

(3.60), March (4.60), February (4.80), December (6.00) and January (6.20). The highest mean population was recorded in the month of January (6.20).

Highest mean population of *T. iridipennis* was recorded in the month of January (3.40) which was on par with the mean population recorded in March, May, April (3.00 each), June (2.60), December (2.40), November, August and February (2.20 each). The lowest mean population was recorded in the month of October (1.60) which was on par with the mean population observed during the months of July, September (1.8 each).

Braunsapis sp. recorded its highest mean population in the month of April (4.00) which was on par with the mean population observed during January (3.60), October (3.20) and December (2.60). When compared with the lowest mean population (1.60) observed in November, significant higher mean populations were observed during May, March, September, June, July, August, February and December (values ranged from 2.00 to 2.60).

Statistically significant mean population was recorded in *Eupetersia* sp. in the month of February (3.40) when compared with the mean population observed during all the other months. The mean population observed during October (2.00), March (2.00), January (1.80) and June (1.40) were on par with each other. A similar condition was observed during the months of January, June July, August and November (values ranged from 1.80 to 1.20). The lowest mean population was observed in the months of April, May, September and

December (values 1.00 each) which was on par with the mean population recorded during July, August, November and June (values ranged from 1.20 to 1.40).

Ants

Solenopsis geminata recorded its highest mean population (Table 6) in the month of May (7.40) which was on par with the mean population recorded in the months of March, June, February (6.80 each), September (6.20), January (6.00), October (5.80), December and August (5.60 each). When compared with the lowest mean population recorded in the month of April (4.60), significant higher mean populations were recorded in the months of May, June, February, September, January, October, August and December (values ranged from 7.40 to 5.60).

High and on par mean populations were recorded in *M. brunnea* in the months of January (7.00), December (6.80), March (6.60), April (6.40), October (6.20), July (5.80) and June (5.40). Similarly low and on par mean populations were recorded in the months of November (4.60), May (4.80), September, August, February (5.00 each), June (5.40), July (5.80), October (6.20) and April (6.40).

P. spathulifera recorded its highest mean population in the month of January (6.40). When compared with the lowest mean population observed in the month of December (4.20), significant higher mean populations were

Table 6. Mean population of various species of ants observed on the coconut inflorescence over a period of one year

Month	Number of ants								
	A1	A2	A3	A4	A5	A6	A7	A8	A9
March '04	6.80 (2.60)	6.60 (2.56)	6.10 (2.48)	5.00 (2.21)	1.00 (1.00)	2.00 (1.41)	1.00 (1.00)	1.20 (1.08)	1.80 (1.33)
April	4.60 (2.11)	6.40 (2.50)	5.00 (2.15)	5.00 (2.10)	1.40 (1.17)	2.00 (1.39)	1.40 (1.17)	1.20 (1.08)	1.40 (1.17)
May	7.40 (2.72)	4.80 (2.18)	5.20 (2.28)	5.20 (2.24)	1.60 (1.25)	2.40 (1.54)	1.20 (1.08)	1.80 (1.33)	1.40 (1.17)
June	6.80 (2.60)	5.40 (2.32)	5.20 (2.27)	5.00 (2.22)	1.60 (1.25)	1.20 (1.08)	1.20 (1.08)	1.80 (1.33)	1.80 (1.33)
July	5.60 (2.35)	5.80 (2.38)	5.40 (2.31)	4.80 (2.17)	1.80 (1.29)	1.60 (1.25)	1.40 (1.17)	1.00 (1.00)	1.20 (1.08)
August	5.60 (2.36)	5.00 (2.21)	5.40 (2.29)	7.00 (2.65)	1.60 (1.25)	1.00 (1.00)	1.60 (1.25)	1.20 (1.08)	2.00 (1.41)
September	6.20 (2.46)	5.00 (2.20)	5.80 (2.40)	5.00 (2.22)	1.40 (1.17)	1.00 (1.00)	1.80 (1.33)	1.60 (1.25)	1.20 (1.08)
October	5.80 (2.40)	6.20 (2.49)	5.60 (2.35)	5.40 (2.29)	2.40 (1.49)	1.20 (1.08)	1.40 (1.15)	1.40 (1.17)	1.20 (1.08)
November	5.20 (2.27)	4.60 (2.13)	4.60 (2.11)	5.80 (2.39)	1.60 (1.25)	1.40 (1.17)	1.40 (1.17)	1.00 (1.00)	1.00 (1.00)
December	5.60 (2.36)	6.80 (2.60)	4.20 (2.03)	5.60 (2.34)	2.60 (1.52)	1.40 (1.17)	2.00 (1.38)	1.20 (1.08)	1.00 (1.00)
January '05	6.00 (2.43)	7.00 (2.65)	6.40 (2.52)	4.80 (2.17)	1.40 (1.15)	1.00 (1.00)	1.00 (1.00)	1.60 (1.25)	1.00 (1.00)
February	6.8 0 (2.60)	5.00 (2.21)	6.20 (2.49)	5.60 (2.35)	1.80 (1.33)	1.20 (1.08)	1.40 (1.17)	1.60 (1.25)	1.60 (1.25)
CD	(0.36)	(0.40)	(0.44)	(0.54)	(0.40)	(0.22)	(0.29)	(0.24)	(0.21)

A1: *S. geminata*, A2: *M. brunnea*, A3: *P. spathulifera*, A4: *Cardiocondyla* sp.
A5: *Monomorium* sp., A6: *Dolichoderus* sp., A7: *Camponotus rufoglaucus*
A8: *C. sericeus*, A9: *O. smaragdina*
Transformed values are in parenthesis

recorded in the months of March, February and January (values ranged from 6.10 to. 6.40). Similar mean populations were recorded in the months of November (4.60), April (5.00), June, May (5.20 each), August, July (5.40 each), October (5.60), September (5.80), March (6.10), February (6.20) and January (6.40).

The highest mean population of *Cardiocondyla* sp. was recorded during August (7.00) which was on par with the mean population recorded in the months of November (5.80), February (5.60), December (5.60), October (5.40), May (5.20), June, September and March (5.00 each). The lowest mean population was recorded in the month of January and July (4.80 each).

Monomorium sp. recorded its highest mean population in the month of December (2.60). It was however on par with the mean population recorded in the months of October (2.40), February, July (1.80 each), May, June, August, November (1.60 each), April, September and January (1.40 each). The lowest mean population was recorded in the month of March (1.00) which was on par with the mean population observed during January, September, April, November, August, June, May, July and February.

The lowest mean population of *Dolichoderus* sp. was recorded in the month of August (1.00) which was on par with the mean population recorded during September, January (1.00 each), June, October, February (1.20 each).the mean population during November and December (1.40 each) showed similar

trend. On par mean populations were also recorded in the months of July (1.60), April and March (2.00 each). The highest mean population was recorded in the month of May (2.40).

Camponotus rufoglaucus recorded its highest mean population in the month of December (2.00) which was on par with the mean population during September (1.80), August (1.60), April, July, November and October (1.40 each). Similarly the lowest mean population was recorded during January (1.00) which was on par with the mean population during March, May, June, October, April, July, November, February and August (values ranged from 1.40 to 1.60).

High but statistically similar mean population of *C. sericeus* were recorded in the months of May, June (1.80 each), September, January, February (1.60 each) and October (1.40). Lower and on par mean population were recorded in the months of July (1.00), November (1.00), March, April, August, December (1.20 each) and October (1.40).

O. smaragdina recorded its highest mean population in the month of August (2.00). When compared with the lowest mean population recorded during November, December and January (1.00 each), significant higher mean population were recorded in the months of February (1.60), March (1.80), June (1.80) and August (2.00). Statistically similar mean populations were recorded during the month of February, April, May, July, September and October.

Flies

Hemipyrellia sp. recorded its highest mean population (Table 7) in November (2.60). When compared with the lowest mean population observed during April (1.20), significant higher mean population were recorded in May, June, August (2.00 each), September (2.20) and November (2.60). Statistically same mean population were observed during May, June, August, December, March, October and February (values ranged from 2.00 to 1.80).

When compared with the lowest mean population, observed in *B. cucurbitae*, during May and June (1.20 each), significant higher mean populations were observed during December, February, July (2.00 each), January (2.40) and March (2.80). The mean populations were similar in the months of January, July, December, February, August and November.

B. dorsalis recorded statistically similar mean population throughout the year (values ranged from 2.00 to 1.60).a similar condition was also noticed in case of *M. domestica* (values ranged from 2.00 to 1.00).

Statistically significant and highest mean population was recorded in *G. brevirostris* in February (3.00). Statistically high and on par mean populations were observed during the months of July, August, January (2.00 each), March, June, December and November (1.80 each).

Sarcophaga sp. recorded its highest mean population in January (3.00). Mean populations recorded in March (2.00), April (1.80), May (1.60),

Table 7. Mean population of various species of flies observed on the coconut inflorescence over a period of one year

Month	Number of flies					
	F1	F2	F3	F4	F5	F6
March '04	1.80 (1.33)	2.80 (1.66)	2.00 (1.39)	1.00 (1.00)	1.80 (1.33)	2.00 (1.38)
April	1.20 (1.08)	1.40 (1.17)	1.80 (1.31)	1.40 (1.17)	1.40 (1.17)	1.80 (1.33)
May	2.00 (1.41)	1.20 (1.08)	1.80 (1.28)	1.40 (1.17)	1.00 (1.00)	1.60 (1.25)
June	2.00 (1.41)	1.20 (1.08)	1.80 (1.33)	2.00 (1.41)	1.80 (1.33)	1.00 (1.00)
July	1.40 (1.17)	2.00 (1.41)	1.80 (1.33)	2.00 (1.41)	2.00 (1.41)	1.00 (1.00)
August	2.00 (1.41)	1.80 (1.33)	1.80 (1.31)	2.00 (1.41)	2.00 (1.41)	1.00 (1.00)
September	2.20 (1.48)	1.40 (1.17)	1.60 (1.23)	2.00 (1.41)	1.40 (1.17)	1.40 (1.17)
October	1.80 (1.33)	1.40 (1.17)	1.80 (1.31)	1.80 (1.33)	1.40 (1.15)	1.20 (1.08)
November	2.60 (1.59)	1.80 (1.28)	1.60 (1.25)	1.20 (1.08)	1.80 (1.29)	1.00 (1.00)
December	2.00 (1.37)	2.00 (1.39)	2.00 (1.41)	1.00 (1.00)	1.80 (1.33)	1.40 (1.15)
January '05	1.40 (1.17)	2.40 (1.54)	2.00 (1.41)	1.00 (1.00)	2.00 (1.41)	3.00 (2.00)
February	1.80 (1.33)	2.00 (1.39)	1.80 (1.33)	1.00 (1.00)	3.00 (1.73)	3.00 (1.96)
CD	(0.26)	(0.30)	90.33)	(0.15)	(0.25)	(0.29)

F1: *Hemipyrellia* sp., F2: *Bactrocera cucurbitae*, F3: *B. dorsalis*, F4: *Musca domestica* F5: *Graptomyza brevirostris*, F6: *Sarcophaga* sp.
Transformed values are in parenthesis

September and December (1.40 each) showed no significant difference among them. Lowest mean populations were recorded in June, July, August and November (1.00 each).

Wasps

The data on the studies of the seasonal occurrence of wasp activity is presented in the Table 8. *Chalybion bengalense* recorded its lowest mean population in the month of May and December (1.40 each). The highest mean population was however recorded in the month of June (2.40) which was on par with the mean population observed during August (2.00), April (2.00), July, November, January, March (1.80 each), October and February (1.60 each).

P. hebraeus recorded statistically similar mean population throughout the year. The highest mean population occurred in the month of July (2.00) whereas the lowest mean population was recorded in the months of April, September and November (1.40 each).

The highest mean population of *R. variegata* was recorded in the month of February (3.60) which were on par with mean population observed during March, September and January (3.00 each). When compared with the lowest mean population recorded in the months of May, July, August and October (1.20 each), significant higher mean population were observed during November, December, January, September, March and February (values ranged from 2.00 to 3.60).

Table 8. Mean population of various species of wasps observed on the coconut inflorescence over a period of one year

Month	Number of wasps				
	W1	W2	W3	W4	W5
March '04	1.80 (1.31)	1.60 (1.25)	3.00 (1.73)	2.00 (1.41)	2.00 (1.41)
April	2.00 (1.39)	1.40 (1.17)	1.40 (1.17)	2.40 (1.54)	1.00 (1.00)
May	1.40 (1.17)	1.60 (1.25)	1.20 (1.08)	2.20 (1.44)	1.00 (1.00)
June	2.40 (1.52)	1.80 (1.31)	1.40 (1.15)	1.80 (1.29)	1.00 (1.00)
July	1.80 (1.33)	2.00 (1.41)	1.20 (1.08)	1.80 (1.29)	1.00 (1.00)
August	2.00 (1.41)	1.60 (1.25)	1.20 (1.08)	1.00 (1.00)	1.00 (1.00)
September	1.80 (1.33)	1.40 (1.17)	3.00 (1.73)	2.20 (1.44)	1.20 (1.08)
October	1.60 (1.25)	1.60 (1.25)	1.20 (1.08)	2.00 (1.41)	1.00 (1.00)
November	2.00 (1.33)	1.40 (1.17)	2.00 (1.41)	1.40 (1.17)	1.00 (1.00)
December	1.40 (1.17)	1.60 (1.25)	2.60 (1.60)	1.60 (1.25)	1.00 (1.00)
January '05	1.80 (1.33)	1.80 (1.33)	3.00 (1.71)	1.40 (1.15)	1.00 (1.00)
February	1.60 (1.25)	1.60 (1.25)	3.60 (1.88)	3.00 (1.73)	2.00 (1.41)
CD	(0.35)	(0.28)	(0.26)	(0.35)	(0.07)

W1: *Chalybion bengalense*, W2: *Polistes hebraeus*, W3: *Ropalidia variegata*, W4: *Vespa cincta*, W5: *Vespa* sp.
Transformed values are in parenthesis

V. cincta recorded its highest mean population in the month of February (3.00). Statistically same mean population were recorded during April (2.40), May (2.20), September (2.20), March (2.00), October (2.00), June (1.80), July (1.80) and December (1.60). The lowest mean population was recorded during August (1.00).

Statistically similar mean population was observed in *Vespa* sp. during the months of April, May, June, July, August, October, November, December and January (1.00 each). Highest mean population was recorded in the months of March and February (2.00 each).

Beetles and Moths

Different species of beetles and moths were observed on the coconut inflorescence (Table 9). *O. versicolor* recorded statistically similar mean population throughout the year. Although, the highest mean population was observed in April and October (1.80 each) and the lowest mean population in May, June, July, September, January and February (1.40 each).

Oxycetonia sp. also followed the same condition by foraging to the coconut inflorescence in numbers that were statistically same throughout the year (values ranged from 1.80 to 1.40).

The lowest mean population of *E. polymena* was observed in September, October, November, December, January and February (1.00 each) which were on par with the mean population recorded in May, June and August (1.20 each).

Table 9. Mean population of various species of beetles and moths observed on the coconut inflorescence over a period of one year

Month	Number of beetles		Number of moths	
	B1	B2	M1	M2
March '04	1.60 (1.25)	1.60 (1.25)	1.80 (1.33)	1.00 (1.00)
April	1.80 (1.33)	1.80 (1.33)	1.40 (1.17)	1.20 (1.08)
May	1.40 (1.17)	1.80 (1.33)	1.20 (1.08)	1.40 (1.17)
June	1.40 (1.17)	1.40 (1.17)	1.20 (1.08)	1.80 (1.33)
July	1.40 (1.17)	1.80 (1.33)	1.40 (1.17)	1.20 (1.08)
August	1.60 (1.25)	1.40 (1.17)	1.20 (1.08)	1.00 (1.00)
September	1.40 (1.17)	1.60 (1.25)	1.00 (1.00)	1.00 (1.00)
October	1.80 (1.33)	1.60 (1.25)	1.00 (1.00)	1.00 (1.00)
November	1.60 (1.25)	1.40 (1.17)	1.00 (1.00)	1.00 (1.00)
December	1.60 (1.25)	1.60 (1.25)	1.00 (1.00)	1.00 (1.00)
January '05	1.40 (1.17)	1.80 (1.33)	1.00 (1.00)	1.00 (1.00)
February	1.40 (1.17)	1.40 (1.17)	1.00 (1.00)	1.00 (1.00)
CD	(0.28)	(0.27)	(0.18)	(0.14)

B1: *Oxycetonia versicolor*. B2: *Oxycetonia* sp.
M1: *Euchromia polymena*, M2: *Melanitis leda ismene*
Transformed values are in parenthesis

Highest mean population was recorded in March (1.80) which was statistically similar to the mean population observed in April and July (1.40 each).

M. leda ismene recorded significant higher mean population in June (1.80) when compared with the mean population of all other months. The lowest mean population was recorded in May, August, September, October, November, December, January, February and March(1.00 each). Statistically similar mean population were recorded in the months of May (1.40), July and April (1.20 each).

4.2 SEASONAL INFLUENCE ON DIFFERENT INSECT SPECIES

The results on the studies of the seasonal influence on insect activity are presented in the Table 10.

Bees

The population of *A. mellifera* showed a highly significant positive correlation with maximum temperature (r value = 0.7515). It was also positively correlated with wind speed and negatively correlated with minimum temperature, relative humidity and rainfall and the relationships were non significant. The population of *A. cerana indica* showed a highly significant positive correlation with maximum temperature (r value = 0.7515). It was also positively correlated with wind speed but negatively correlated with minimum temperature, relative humidity and rainfall. The population of *T. iridipennis* also showed a high significant and positive correlation with maximum

Table 10 Correlation between various insect species and different weather parameters.

Insect species	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity	Wind speed (km/h)	Rainfall (cm)
A. mellifera	0.7515**	-0.0839	-0.1148	0.4773	-0.0389
A. cerana indica	0.7515**	-0.0839	-0.1148	0.4773	-0.0389
T. iridipennis	0.7699**	0.1620	-0.5032	0.7640*	-0.2112
Braunsapis sp	0.6003	-0.1486	-0.1086	0.3963	-0.2872
Eupetersia sp	0.3934	0.2779	-0.1383	0.5110	-0.3203
S. geminata	0.3748	0.3179	-0.2667	0.3225	-0.1988
M. brunnea	-0.2138	-0.6674*	0.4386	-0.0488	-0.1743
Dolichoderus sp	0.4233	0.0328	0.0286	0.4162	-0.3259
C. sericeus	0.5276	-0.5461	0.1607	0.2193	-0.0936
Hemipyrellia sp	-0.3771	-0.1958	0.3108	-0.5831*	-0.8240**
M. domestica	-0.4812	-0.1921	0.1983	-0.3639	0.2344
G. brevirostris	0.6576*	-0.3373	0.1753	0.2821	-0.1485
P. hebraeus	0.0150	0.4041	-0.5439	-0.1715	-0.2872
C. bengalense	-0.2423	-0.3956	0.3692	-0.5281	0.4398
Oxycetonia versicolor	-0.0191	0.3481	0.0082	0.1847	0.0872
Oxycetonia sp.	0.1663	0.5539	-0.1458	0.3265	-0.4227

*Significance at 5% - 0.5760
**Significance at 1% - 0.7079

temperature and wind speed with r-values 0.7699 and 0.7640 respectively. It was however negatively correlated with relative humidity and rainfall but positively correlated with minimum temperature though the relationship was not significant. A positive correlation was observed between the populations of *Braunsapis* sp. and maximum temperature with r-values 0.6003. Also the population was positively correlated with wind speed and negatively correlated with minimum temperature, relative humidity and rainfall and the relationship was not significant. Population of *Eupetersia* sp. exhibited a positive correlation with maximum temperature, minimum temperature and wind speed. It was however negatively correlated with relative humidity and rainfall and the relationship was non significant.

Ants

The population of *S. geminata* showed positive correlation with maximum temperature, minimum temperature and wind speed. It also had negative correlation with relative humidity and rainfall and none of the relationships were significant. *M. brunnea* showed a significant negative correlation with minimum temperature (r value = 0.6674) but had a positive correlation with relative humidity and negative correlation with maximum temperature, wind speed and rainfall. *Dolichoderus* sp. was positively correlated with maximum temperature, relative humidity and wind speed. It however showed a negative correlation with minimum temperature and rainfall. The population of

C. sericeus did not had any significant correlation with any one of the weather parameters, even though it was positively correlated with maximum temperature, relative humidity and wind speed and negatively correlated with rainfall and minimum temperature.

Flies

Population of *Hemipyrellia* sp. showed a significant negative correlation with wind speed (r value = - 0.5831) and highly significant negative correlation with rainfall (r value = 0.8240). It was positively correlated with relative humidity and negatively correlated with maximum temperature and minimum temperature and the relationship was not significant. The population of *M. domestica* had no significant correlation with any of the weather parameters even though it showed a negative correlation with maximum temperature, minimum temperature and wind speed. It had a positive correlation with relative humidity and rainfall. *G. brevirostris* showed a significant positive correlation with maximum temperature (r value = 0.6576). It was also positively correlated with relative humidity and wind speed but negatively correlated with minimum temperature and rainfall.

Wasps

The population of *P. hebraeus* had a negative correlation with maximum temperature, relative humidity, wind speed and rainfall but showed a positive correlation with minimum temperature. *C. bengalense* population was

negatively correlated with maximum temperature, minimum temperature, and wind speed. It showed a positive correlation with relative humidity and rainfall.

Beetles

The population of *O. versicolor* had a positive correlation with minimum temperature, relative humidity, wind speed and rainfall. However, the relationship with maximum temperature showed a negative correlation and was not significant. *Oxycetonia* sp. also had a positive correlation with maximum temperature, minimum temperature and wind speed. It was but negatively correlated with humidity and rainfall.

4.3 ASSESSMENT OF REATIVE SAFETY/TOXICITY OF DIFFERENT CHEMICALS IN LABORATORY

The results of the experiment to determine the relative safety/toxicity of different insecticides to honeybees are presented in Table 11.

30 MAT

A. mellifera recorded the highest mortality in carbaryl 0.1 per cent (53.33 per cent) treatment followed by dicofol 0.1 per cent (50.00 per cent) and quinalphos 0.05 per cent (46.66 per cent). Malathion 0.1 per cent caused 36.66 per cent mortality where as endosulfan 0.05 per cent caused 30.00 per cent mortality during the same time period. Dimethoate 0.1 per cent was the least toxic chemical insecticide which recorded only 26.66 per cent mortality.

Table 11. Effect of various pesticides on different species of honeybees under laboratory conditions.

Treatments	Mortality of honeybees at different time intervals (%)																	
	30 min			60 min			90 min			120 min			12 h			24 h		
	Am	Aci	Ti	Am	Aci	Ti	Am	Aci	Ti	Am	Aci	Ti	Am	Aci	Ti	Am	Aci	Ti
Carbaryl 0.1%	53.33	56.66	66.66	83.33	80.00	80.00	100	100	100	-	-	-	-	-	-	-	-	-
Dicofol 0.1%	50.00	50.00	60.00	66.66	53.33	73.33	83.33	83.33	100	100	100	-	-	-	-	-	-	-
Malathion 0.1%	36.66	36.66	30.00	46.66	36.66	56.66	70.00	83.33	100	100	100	-	100	-	-	-	-	-
Quinalphos 0.05%	46.66	46.66	50.00	50.00	50.00	53.33	63.33	66.66	73.33	100	100	100	-	-	-	-	-	-
Endosulfan 0.05%	30.00	30.00	50.00	43.33	46.66	53.33	50.00	50.00	60.00	53.33	70.00	70.00	100	100	100	-	-	-
Dimethoate 0.1%	26.66	30.00	13.33	43.33	33.33	20.00	56.66	46.66	40.00	100	100	100	-	-	-	-	-	-
Neemazal 1%	0.00	0.00	3.33	0.00	0.00	3.33	0.00	0.00	3.33	3.33	0.00	6.66	23.33	3.33	26.66	33.33	33.33	30.00
NOGE 2%	0.00	0.00	0.00	0.00	0.00	3.33	0.00	0.00	3.33	0.00	0.00	6.66	13.33	16.66	23.33	16.66	23.33	26.66
Control	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

NOGE – Neem oil garlic emulsion

Am: *A. mellifera,* Aci: *A. cerana indica,* Ti: *T. iridipennis*

Azadirachtin 0.004 per cent and neem oil garlic emulsion 2.0 per cent did not cause any mortality to bees.

The order of toxicity of treatments to *A. cerana indica* were carbaryl 0.1 per cent (56.66 per cent) > dicofol 0.1 per cent (50.00 per cent) > quinalphos 0.05 per cent (46.66 per cent) > malathion 0.1 per cent (36.66 per cent) >endosulfan 0.05 per cent = dimethoate 0.1 per cent (30.00 per cent). Azadirachtin 0.004 per cent and neem oil garlic emulsion 2.0 per cent did not cause any mortality. No mortality was observed in the control also.

Carbaryl 0.1 per cent was the most toxic chemical to *T. iridipennis* as it caused 66.66 per cent mortality followed by dicofol 0.1 per cent which recorded 60.00 per cent mortality. Quinalphos 0.05 per cent and endosulfan 0.05 per cent were equally toxic as they recorded 50.00 per cent mortality each. Dimethoate 0.1 per cent caused 13.33 per cent mortality where as azadirachtin 0.004 per cent caused only 3.33 per cent mortality of the bees. Neem oil garlic emulsion 2.0 per cent caused no mortality and therefore was the safest treatment.

60 MAT

The order of toxicity of different insecticide to *A. mellifera* were carbaryl 0.1 per cent (83.33per cent) > dicofol 0.1 per cent (66.66 per cent) > quinalphos 0.05 per cent (50.00 per cent) > endosulfan 0.05 per cent (46.66 per cent) > malathion 0.1 per cent (43.33 per cent) = dimethoate 0.1 per cent (43.33 per

cent). Azadirachtin 0.004 per cent and neem oil garlic emulsion 2.0 per cent caused no mortality. The control treatment also recorded zero mortality.

Carbaryl 0.1 per cent (80.00 per cent) > dicofol 0.1 per cent (53.33 per cent) > quinalphos 0.05 per cent (50.00 per cent) > endosulfan 0.05 per cent (46.66 per cent) > malathion 0.1 per cent (36.66 per cent) > dimethoate 0.1 per cent (33.33 per cent) > azadirachtin 0.004 per cent (0.00 per cent) = neem oil garlic emulsion 2.0 per cent (0.00 per cent) were the order of toxicity to *A. cerana indica.*

The highest toxicity was shown by carbaryl 0.1 per cent, which recorded 80.00 per cent mortality, followed by dicofol 0.1 per cent and malathion 0.1 per cent with mortality 73.33 per cent and 56.66 per cent respectively in *T. iridipennis.* Both quinalphos 0.05 per cent and endosulfan 0.05 per cent were equally toxic as it reduced the bee population by 53.33 per cent each. Dimethoate 0.1 per cent recorded 20.00 per cent mortality while azadirachtin 0.004 per cent and neem oil garlic emulsion 2.0 per cent recorded a mortality of 3.33 per cent each.

90 MAT

There was cent percent mortality recorded in carbaryl 0.1 per cent treatment in *A. mellifera.* The next orders of toxicity were dicofol 0.1 per cent (83.33 per cent). Malathion 0.1 per cent (70.00 per cent) > quinalphos 0.05 per cent (63.33 per cent) > dimethoate 0.1 per cent (56.66 per cent) > endosulfan

0.05 per cent (50.00 per cent). Azadirachtin 0.004 per cent and neem oil garlic emulsion 2.0 per cent along with the control recorded zero mortality.

A. cerana indica also recorded cent percent mortality in carbaryl 0.1 per cent treatment. Dimethoate 0.1 per cent showed 46.66 per cent mortality which was however less toxic than dicofol 0.1 per cent and malathion 0.1 per cent which recorded 83.33 per cent mortality each. Endosulfan 0.05 per cent caused 50.00 per cent mortality where as quinalphos 0.05 per cent recorded 66.66 per cent mortality. Azadirachtin 0.004 per cent, neem oil garlic emulsion 2.0 per cent and the control treatment recorded zero mortality of bees.

Carbaryl 0.1 per cent, dicofol 0.1 per cent and malathion 0.1 per cent recorded 100 per cent mortality in *T. iridipennis*. Quinalphos 0.05 per cent caused 73.33 per cent mortality while endosulfan 0.05 per cent and dimethoate 0.1 per cent caused 60.00 per cent and 40.00 per cent mortality respectively. Both azadirachtin 0.004 per cent and neem oil garlic emulsion 2.0 per cent caused 3.33 per cent mortality each during this time period.

120 MAT

A. mellifera recorded 96.66 per cent mortality in malathion 0.1 per cent treatment. The dicofol 0.1 per cent treatment completely killed all bees and similarly Quinalphos 0.05 per cent also followed the same trend. Endosulfan 0.05 per cent recorded 53.33 per cent mortality. The lowest mortality of *A. mellifera* was recorded in azadirachtin 0.004 per cent treatment (3.33 per

cent). No mortality was observed in neem oil garlic emulsion 2.0 per cent and the control treatments.

There was cent percent mortality recorded in dicofol 0.1 per cent, malathion 0.1 per cent, quinalphos 0.05 per cent and dimethoate 0.1 per cent treatments in *A. cerana indica*. Endosulfan 0.05 per cent recorded 70.00 per cent. However, no mortality was noticed in azadirachtin 0.004 per cent and neem oil garlic emulsion 2.0 per cent treatments during this time period.

In *T. iridipennis*, 100 per cent mortality was noticed in case of dimethoate 0.1 per cent and quinalphos 0.05 per cent treatments after 120 min. Seventy per cent mortality of bees occurred in endosulfan 0.05 per cent treatment. Azadirachtin 0.004 per cent and neem oil garlic emulsion 2.0 per cent and the control treatment recorded zero percent mortality each and therefore were comparatively safe.

12 HAT

There was cent percent mortality of *A. mellifera* in malathion 0.1 per cent, and endosulfan 0.05 per cent treatments. Azadirachtin 0.004 per cent and neem oil garlic emulsion 2.0 per cent recorded 23.33 per cent and 13.33 per cent mortality respectively. No mortality of bees occurred in control treatments.

Endosulfan 0.05 per cent caused hundred percent mortality in *A. cerana indica*. Azadirachtin 0.004 per cent was comparatively safe as it recorded only 3.33 per cent mortality as against 16.66 per cent mortality with

neem oil garlic emulsion 2.0 per cent treatment. A similar condition was also noticed in *T. iridipennis* with chemical insecticide treatments. However, azadirachtin 0.004 per cent caused a higher mortality of 26.66 per cent than neem oil garlic emulsion 2.0 per cent in which the mortality of bees was found to be 23.33 per cent.

24 HAT

There was no relevance of chemical insecticides here as it already caused 100 percent mortality in all treatments for *A. mellifera, A. cerana indica* and *T. iridipennis* within 12 h of treatment. The mortality caused by neem oil garlic emulsion 2.0 per cent was lower in these three bees with values 16.66 per cent, 23.33 per cent and 26.66 per cent as against the mortality caused by azadirachtin 0.004 per cent which recorded 33.33 per cent, 33.33 per cent and 30.00 per cent mortality respectively. No mortality was recorded in the control treatments.

Discussion

5. DISCUSSION

The role of insects in the cross-pollination of plants was known to man from time immemorial. Pollination of cross-pollinated crop demands the assistance of an external agency to carry out this process. Although, many agents are involved, insects are proved to play a better role. Mostly insects belonging to Hymenoptera, Diptera, Coleoptera, and Lepidoptera were found to visit the inflorescences of such plants. Among these, hymenopterans, more specifically honeybees were regarded as the most efficient pollinators of plants.

5.1 DIFFERENT INSECT SPECIES ON COCONUT INFLORESCENCE

A number of insects are known to visit the coconut inflorescence during the flowering period. The male flowers provide copious amounts of pollen (272 million pollen grains per inflorescence) to the flower visitors (Aldaba, 1921). The insect fauna associated with coconut palm differs widely in different parts of the world. Many workers (Huggins, 1928; Patel, 1938; Menon and Pandalai, 1958; Whitehead, 1965; Sholdt, 1966; Suresh, 2002 and Shanmugavelu *et al.*, 2002) had observed different insects which included bees, ants, wasps, earwigs, flies, mites and beetles visiting the coconut inflorescence. The present study also revealed that the coconut inflorescence was visited by different types of insect species *viz.*, bees, ants, flies, wasps, beetles and moths. The female flowers provide enough amount of nectar to these visitors, when it becomes receptive, but only for a couple of days.

Among the 30 numbers of insect species, which were observed and recorded during the present study, visiting the inflorescence of *Cocos nucifera* at the Instructional Farm, Vellayani, Hymenoptera (66.67 per cent) represented the most dominant insect order followed by Diptera (20.00 per cent), Coleoptera (6.67 per cent) and Lepidoptera (6.67 per cent). Louis and Chelladurai (1984) reported that honeybees constituted 51.19 per cent of the insect visitors on the bloom of coconut trees. The presence of this high percentage of hymenopterans as insect visitors may help in enhancing the pollination of the crop. These may also motivate the coconut growers to conserve the hymenopteran (honeybees) population, if any, or else to place sufficient bee colonies in their gardens so as to get an enhanced yield of the crop by the way of increased pollination. As 16 per cent of the cropped area in Kerala is occupied by coconut, the present findings will help the planters to enhance their productivity by practising bee keeping in their plantations.

Anonymous (1916); Kidavu and Nambiar (1925); Huggins (1928); Davis (1954); Louis and Chelladurai (1984); Mandal (1991); Thampan (1993) and Shanmugavelu *et al.* (2002) considered honeybees as an important pollinator of coconut. The present study also recorded the presence of different species of honeybees visiting the coconut inflorescence (Plate 1 and 2). The honeybee species included *Apis mellifera*, *A. cerana indica*, *A. dorsata* and *Trigona iridipennis*. Among these, *A. mellifera* was the dominant visitor of male flowers followed by *A. cerana indica* and *T. iridipennis*. *A. mellifera* require more quantity of pollen as its food source with regard to its body weight

Apis mellifera

Apis cerana indica

Apis dorsata

Plate 1. Bee species visiting male flowers of the coconut inflorescence

Trigona iridipennis

Braunsapis sp.

Eupetersia sp.

Plate 2. Bee species visiting the coconut inflorescence

compared to other bee species. Since, the coconut male flowers is an abundant source of pollen, which is available to the bees throughout the year, *A. mellifera* tends to visit the inflorescence in more numbers during the male phase. Two new bee species *viz.*, *Braunsapis* sp. and *Eupetersia* sp. were identified as coconut flower foragers in the present study. Although their visits to the palm inflorescence were less frequent when compared to the visits made by *Apis* spp., they were found to carry pollen grains on their body surfaces, which might also aid in the cross-pollination of the palm. Singh (1962); Crane *et al.* (1984), Suryanarayana *et al.* (1990) and Mishra (1995) had suggested that coconut palm is an excellent source of pollen and nectar for the bees to forage upon. The results of the study also revealed that bees collected pollen and nectar from the flowers throughout the year and their visit was only limited by unfavourable weather conditions. Payawal *et al.* (1986) reported that *Cocos nucifera* provided year round pollen source to bees. Similar reports were also made by Ramanujam *et al.* (1993); Nehru *et al.* (1984); Forbes and Cervancia (1994); Diaz and Santana (1996); Kumar *et al.* (1997); Munaan, (1997); and Suresh *et al.* (2003). Thus the result was in line with the findings of the above authors. The abundant source of pollen in the coconut inflorescences, which is the major component of food to bees, reserve scope for bee keeping in coconut gardens. Presence of large number of bees will in turn aid in cross-pollination resulting in an enhanced yield of the crop.

The bee visitation frequency was comparatively higher during the female phase than in male phase in the present study, which may be due to the fact that bees visit the inflorescence with an intention to collect nectar.

Reports of ants visiting the palm inflorescence were made by Kidavu and Nambiar (1925); Huggins (1928); Davis (1954); Sholdt (1966); Louis and Chelladurai (1984); Mandal (1991) and Suresh (2002). Ants *viz.*, *Solenopsis geminata*, *Myrmicaria brunnea*, *Pheidole spathulifera* and *Dolichoderus* sp., (Plate 3 and 4) which visited the coconut inflorescence, have not been reported earlier. Ants visited the inflorescence throughout the day but their role as pollinator of the palm requires further detailed study. Also, the present study revealed that the body of ants carried no or negligible pollen grains from the male flowers and therefore can be considered as inefficient pollinators. This was in line with the suggestions made by Huggins (1928). Ants were seen visiting the coconut inflorescence continuously and at no time the inflorescence was found free of them during the period of observation. The presence of ants in both male and female phase of the coconut inflorescence indicates that they feed on both pollen and nectar.

Dipterans that were found visiting the palm inflorescence in the present study were *Hemipyrellia* sp., *Musca domestica*, *Graptomyza brevirostris* *Sarcophaga* sp., *Bactrocera cucurbitae* and *B. dorsalis* (Plate 5). Aldaba (1921); Kidavu and Nambiar (1925); Davis (1954); Mandal (1991); Suresh (2002) and Shanmugavelu *et al.* (2002) had also recorded the association of different fly species with coconut palm inflorescence. The association of *B. cucurbitae* and *B. dorsalis* are first reports from coconut inflorescence. Flies also mainly visited the female flowers for nectar feeding. They were also active on half opened male flowers and carried very less pollen grains. They may be more attracted by the nectaries present in the male flowers.

Solenopsis geminata

Pheidole spathulifera

Myrmicaria brunnea

Cardiocondyla sp.

Monomorium sp.

Plate 3. Different ant species species observed visiting on the coconut inflorescence

Dolichoderus sp.

Camponotus sericeus

Camponotus rufoglaucus

Oecophylla smaragdina

Plate 4. Different ant species observed visiting on the coconut inflorescence

Bactrocera cucurbitae

Bactrocera dorsalis

Hemipyrellia sp.

Sarcophaga sp.

Graptomyza brevirostris

Musca domestica

Plate 5. Fly species visiting the coconut inflorescence

In the present study, five species of wasps *viz.*, *Chalybion bengalense*, *Polistes hebraeus*, *Ropalidia variegata*, *Vespa cincta* and *Vespa* sp. were seen foraging on the coconut flowers (Plate 6). They foraged mainly for nectar but occasionally visited the male flowers. Sholdt and Mitchell (1967); Louis and Chelladurai (1984); Suresh (2002) and Shanmugavelu *et al.* (2002) had also reported the presence of wasps on the coconut inflorescence. The present study therefore affirms the finding of the above authors. Like ants, wasps also carried very little or no pollen grains on them and therefore not considered useful in cross-pollination. They foraged actively on the female flowers. This indicates the preference of the insect for nectar rather than pollen.

The present study also revealed the presence of two species of beetles *viz.*, *Oxycetonia versicolor* and *Oxycetonia* sp. visiting the coconut inflorescence (Plate 7). They visited the male flowers as pollen feeders. This was in conformity to the reports made by Suresh (2002). Unlike in male flowers, beetles and earwigs were not found on the female flowers in the present study. These insects may be visiting the coconut flowers for collecting pollen and since pollen is not available in the female flowers, its presence is lacking.

Peak Time of Foraging Activity

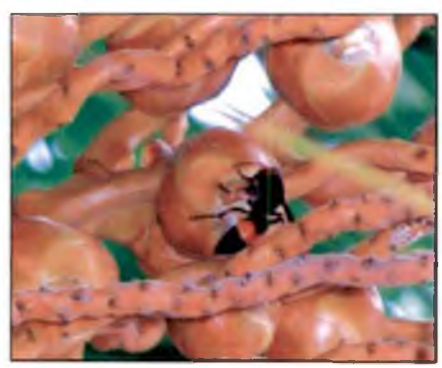
Hymenopterans dominated the number of flower visitors followed by dipterans and coleopterans (Fig.1). Honeybees were the most frequent flower visitor followed by ants, flies, wasps and beetles (Fig. 2).

Polistes hebraeus

Vespa sp.

Ropalidia variegata

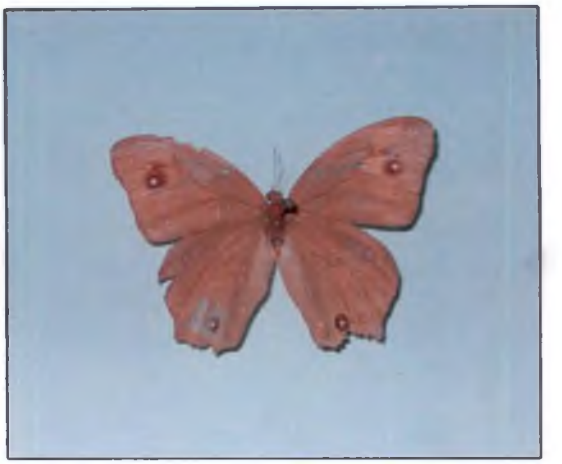
Chalybion bengalense



Vespa cincta

Plate 6. Wasp species visiting the coconut inflorescence

Euchromia polymena



Melanitis leda ismene

Oxycetonia versicolor

Oxycetonia sp.

Plate 7. Moth and Beetle species observed on the coconut inflorescence

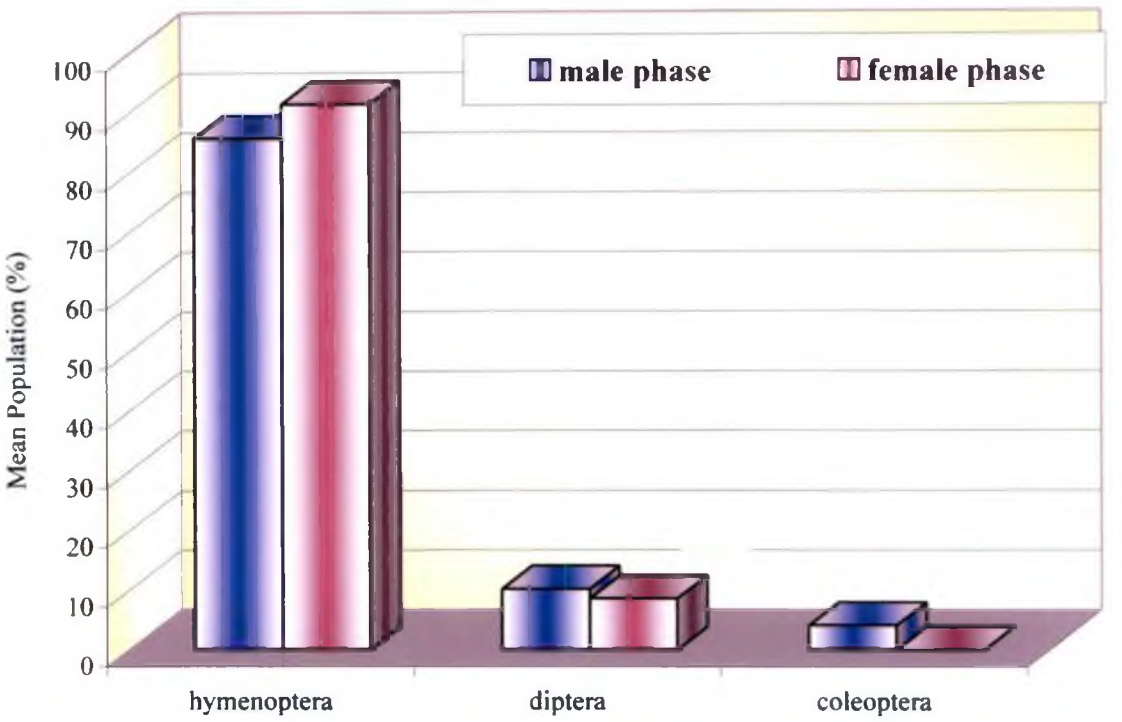


Fig. 1. Comparative abundance of differentorders of insects during various phases of the coconut inflorescence

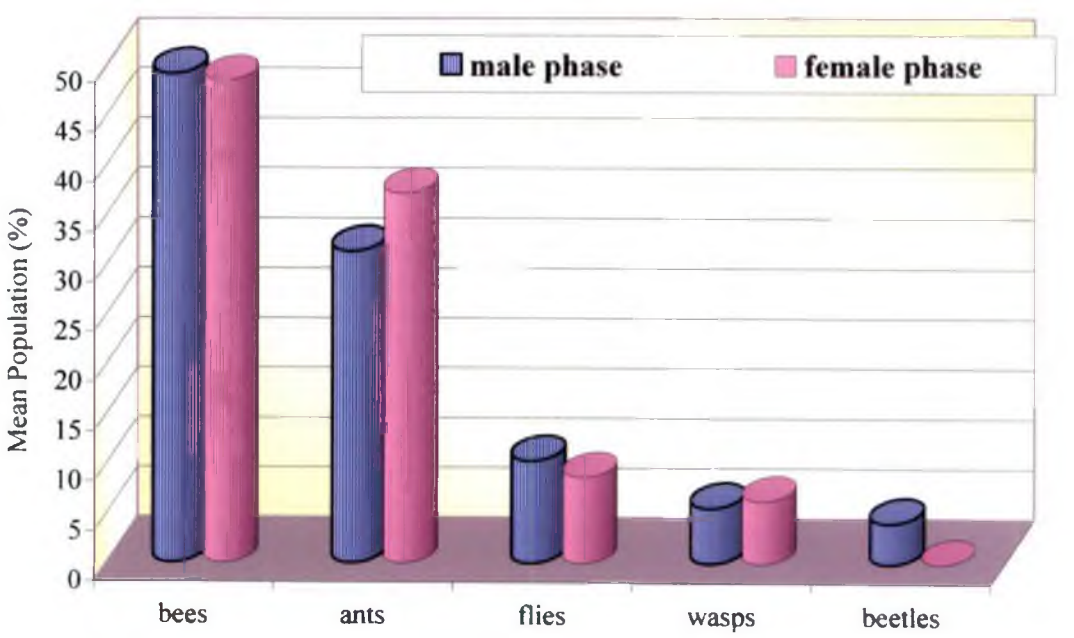


Fig. 2. Comparative abundance of different group of insects during various phases of the coconut inflorescence

It was observed in the present study that the different species of honeybees preferred to visit the coconut inflorescence more actively during the forenoon hours and therefore their population was higher during this period when compared with the population of other insects. The population of ants observed on the coconut inflorescence were high during the forenoon hours. During other time intervals also, their visit did not show much variations. Ants visited the palm inflorescence throughout the day. Flies visited the palm inflorescence with not much variation in their population for the entire period of observations. Like flies, wasps and beetles also did not show any marked preference for a particular time period in a day to visit the coconut inflorescence. However, they exhibited a higher preference to visit the inflorescence during the forenoon hours. The peak time of insect activity when all the species observed on the coconut inflorescence was at 0900 h (3.25) which was higher than all the other time intervals. Also, a second but comparatively smaller peak was observed during 1500 h.

The present study to determine the peak period of foraging activity of different insect species on coconut inflorescence in a day during the male phase revealed that both *A. mellifera* and *A. cerana indica* had their peak period of foraging activity during the forenoon hours (0900 h) while *T. iridipennis* recorded its peak period of foraging activity at 12 noon (Fig. 3). Menon and Pandalai (1958); Mandal (1991) and Muralidharan *et al.* (2001) had reported that maximum flower opening in coconut inflorescence takes place between 0800 h – 1000 h and therefore maximum pollen is collected by honeybees during this period. The peak hours of activity of

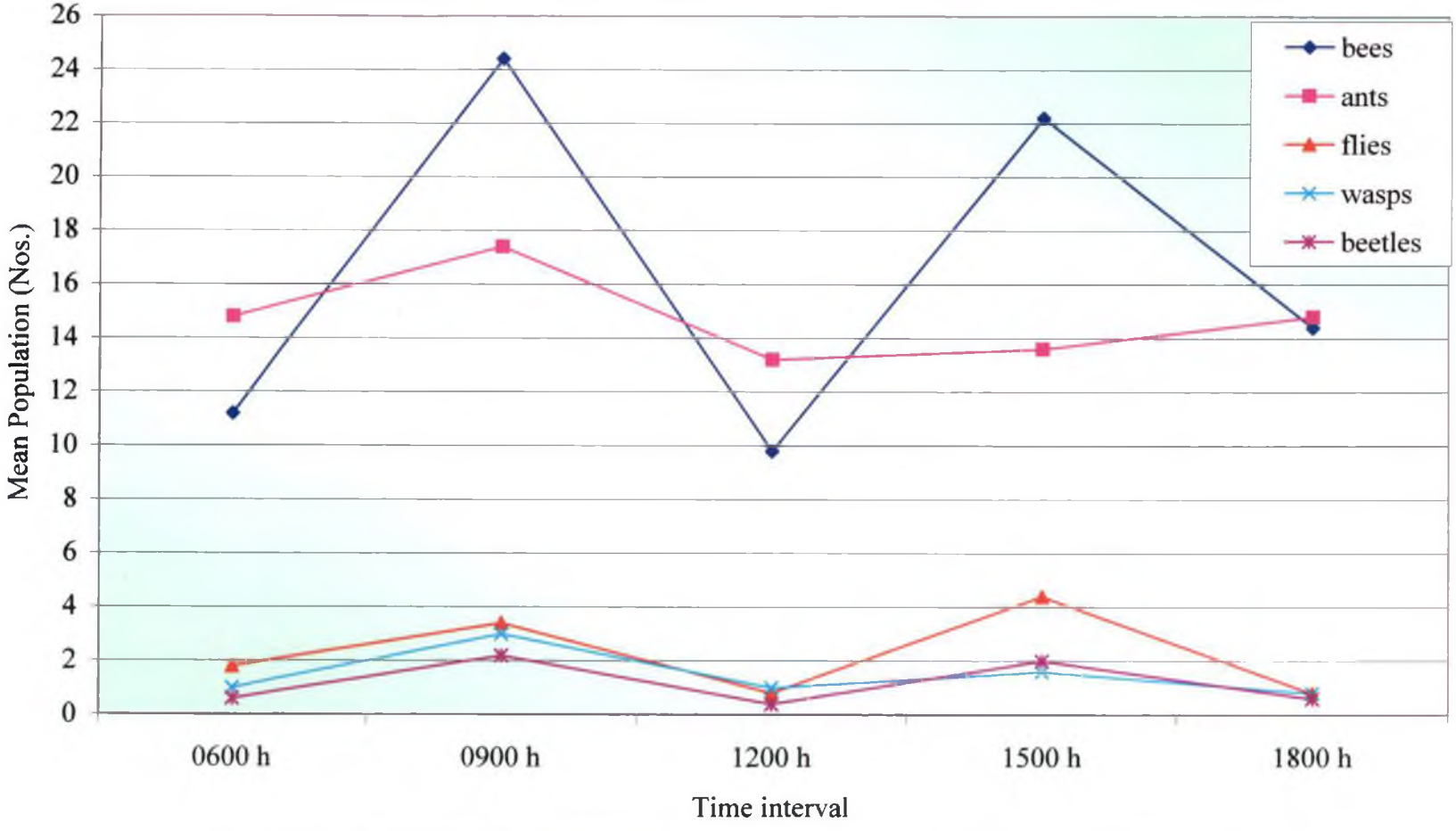


Fig. 3. Foraging activity by different groups of insects at various time intervals

A. mellifera were noticed from 9 am to 11 am with a decline at 12 noon while in case of *A. cerana indica*, the peak hours of activity were found to be from 6 am to 10 am (AICRP, 1998). The result of the present study recorded maximum bee activity at 0900 h and therefore confirms the above findings.

Maximum visit by *T. iridipennis* at 1200 h may be due to the fact that honeybee species exhibit the behaviour of floral preference. Also, *A. mellifera*, *A. cerana indica* needed more pollen as its food source. *T. iridipennis* needed little quantity if pollen that is still available after the visits made by *A. mellifera* and *A. cerana indica*. During 1200 h, maximum number of *T. iridipennis* collects its required pollen which is left out after the visits made by *A. mellifera* and *A. cerana indica* with a view to avoid competition among them. Contradictory to this, Kumar *et al.* (1997) reported that the bees foraged the plants continuously from 0800 h to 1700 h with the peak observed during 1000 h to 1300 h for pollen collection and 1100 h to 1400 h for nectar collection.

The reason why the insects tend to visit the plants during this period was well explained by Priti and Sihag (1998) that when the inflorescence bears maximum number of opened flowers, it attracts maximum number of insects towards it. Sihag and Khatkar (1999 a) also opined in a similar way by suggesting that the honeybee visitation frequency was low at the time of initiation of flowering, which increased gradually and reached a peak during the peak flowering period and then declined with decline in flowering. Several other authors (Arya, 1985; Choi and Oh, 1986; Sinha

and Chakrabarti, 1992; Singh *et al.*, 2000; Vishweshwaraiah *et al.*, 2002 and Singh *et al.*, 2003) have also recorded similar kind of peaks in different crops. The reason for the occurrence of different peak period of activity may be because maximum flower opens at different times in different crops in a day.

It was observed in present study that different bee species showed mutualistic approach towards each other and none of them deterred each other's activity. However, such approaches were not observed between honeybees and wasps. Ants also showed similar responses with flies which tend to visit mostly the female flowers.

Peak Day of Foraging Activity

Male Phase

Data recorded on the insect activity during the male phase, which lasted for 20 days, revealed that the maximum insect activity was found to be on the 13^{th} day. This was earlier reported by Thampan (1993) whereas Menon and Pandalai (1958) and Shanmugavelu *et al.* (2002) were of the opinion that the male phase lasted for 18 - 22 days. The results of the present study are therefore contradictory to this and this may be due to the varietal difference and other environmental factors.

The insect population on the 12^{th}, 14^{th} and 15^{th} day was also equally comparable with the 13^{th} day population. This may be due to the reason that maximum flower opening occurs during these days. This was in confirmity to the reports of Patel (1938); Menon and Pandalai (1958); Mandal (1991) and Muralidharan *et al.* (2001) as they confirmed that on the 15^{th} day

maximum number of male flower opens and therefore the maximum insect visits. However, the slight difference may be attributed to the prevailing weather conditions of the experimentation locality. The insect population was low at the initiation of flower opening, which then gradually increased and reached maximum (on the 13th day) when there were maximum number of flowers and then again declined towards the end of the male phase. Bee visitation therefore can said to be directly proportional to the flower opening trend in coconut. The population of insect was almost negligible towards the end of the male phase and because very less quantity of pollen grains was available, the frequencies of bee visits were also less. Bees collected pollen from half opened flowers and because of their dense hairy bodies, they pick up pollen grains while working on these flowers.

Female Phase

The present study also revealed that the female phase lasted for five days. This is in confirmity with the reports made by Menon and Pandalai (1958); Thampan (1993); Mandal (1991) and Shanmugavelu *et al.* (2002). The maximum number of insects was recorded on the second day, when the buttons were receptive. Almost all the female flowers on an inflorescence were receptive simultaneously and this lasted for only a couple of days. The receptive stage of the female flowers can be easily identified by the presence of a drop of nectar secretion that oozes out from the three nectar orifices located in between the stigma and base of the ovary. As in the male phase, hymenopterans, which included bees, ants and wasps dominated the number of flower visitors. The nectary exudation from the buttons attracted

the insects. The insects after visiting the male flowers of a palm carries pollen grains on them and when it visits the female flowers of the same palm or other palm can effect cross-pollination. It was observed in the study that honeybees carried pollen grains and therefore if sufficient numbers of colonies are maintained in the plantations, it will result in an enhanced yield. Louis and Chelladurai (1984) suggested that honeybees were active on male and female flowers alternatively. *T. iridipennis* however was found to be not very active and therefore collects pollen and nectar rather slowly. In general, honeybees visited the coconut inflorescence throughout the day and at no time the inflorescence was found to be free from them. Although, their population fluctuated widely over different time intervals.

5.2 SEASONAL OCCURRENCE OF DIFFERENT INSECTS ON THE COCONUT INFLORESCENCE

The months of January, February, March, April and December recorded higher populations of bees (Fig. 4). These months coincided with the dry periods. As the frequencies of visits made by bees were directly proportional to the maximum temperature, their foraging activity was enhanced. The population of ants however remained more or less the same throughout the study period. Since pollen and nectar served as food source for them, they foraged the inflorescence continuously. Similarly flies, wasps, beetles and moths were also seen to visit the inflorescence in the same manner.

Among bees, *A. mellifera, A. cerana indica* and *T. iridipennis* visited the coconut inflorescence in higher numbers (Fig. 5). Of these, *A. mellifera* was the

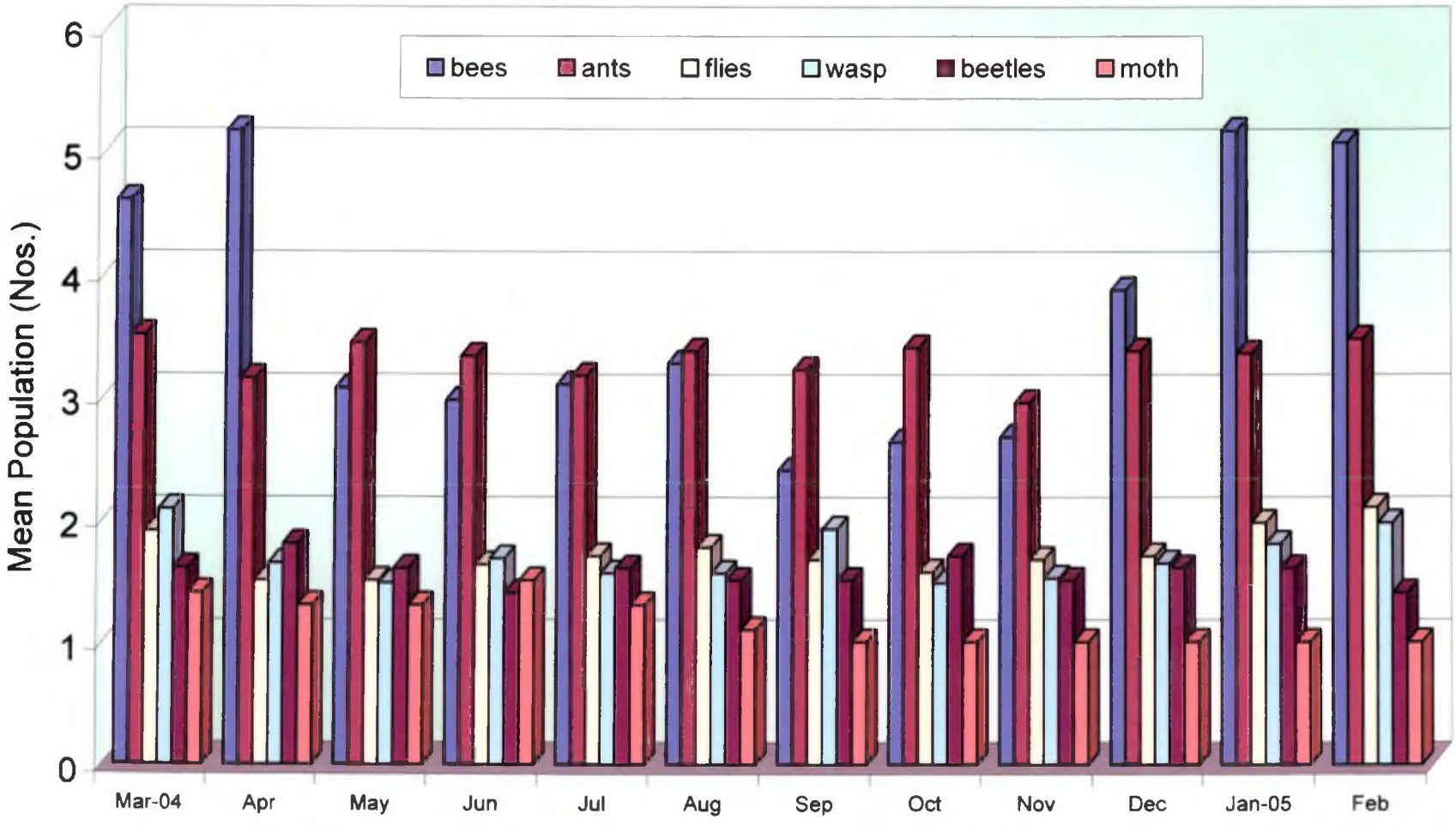


Fig. 4. Population distribution of different group of insects recorded over a period of one year

most dominant flower visitor. This may be because the food requirement of these bees is higher when compared to the other species. *S. geminata, M. brunnea, P. spathulifera* and *Camponotus sericeus* dominated the number of flower visitors among different species of ants. However, all the other observed insect species foraged on the coconut inflorescences in almost similar numbers during the present study.

A. mellifera, A. cerana indica and *T. iridipennis* showed a positive correlation with the maximum temperature. The population of insects visiting the coconut inflorescence was not only floral dependent but also to some extent was dependent on some weather parameters like maximum temperature, minimum temperature, relative humidity, rainfall etc. Although these factors does not seem to influence the insect activity to a large extent, except a few, the results of the current study has brought out some information regarding the correlations between insect activity and the prevailing environmental factors. Paucity of data regarding these aspects was also a limiting factor.

Lee *et al.* (1988) had correlated the foraging honeybees positively with other foraging insects, temperature, light intensity and negatively correlated with humidity. The present study also supported this result. According to Naim and Phadke (1976) the bee colonies were least active and being greatly influenced by rainy days and high humidity. Sinha and Chakrabarti (1992) had also reported a close association between the insect activity and prevalent weather parameters.

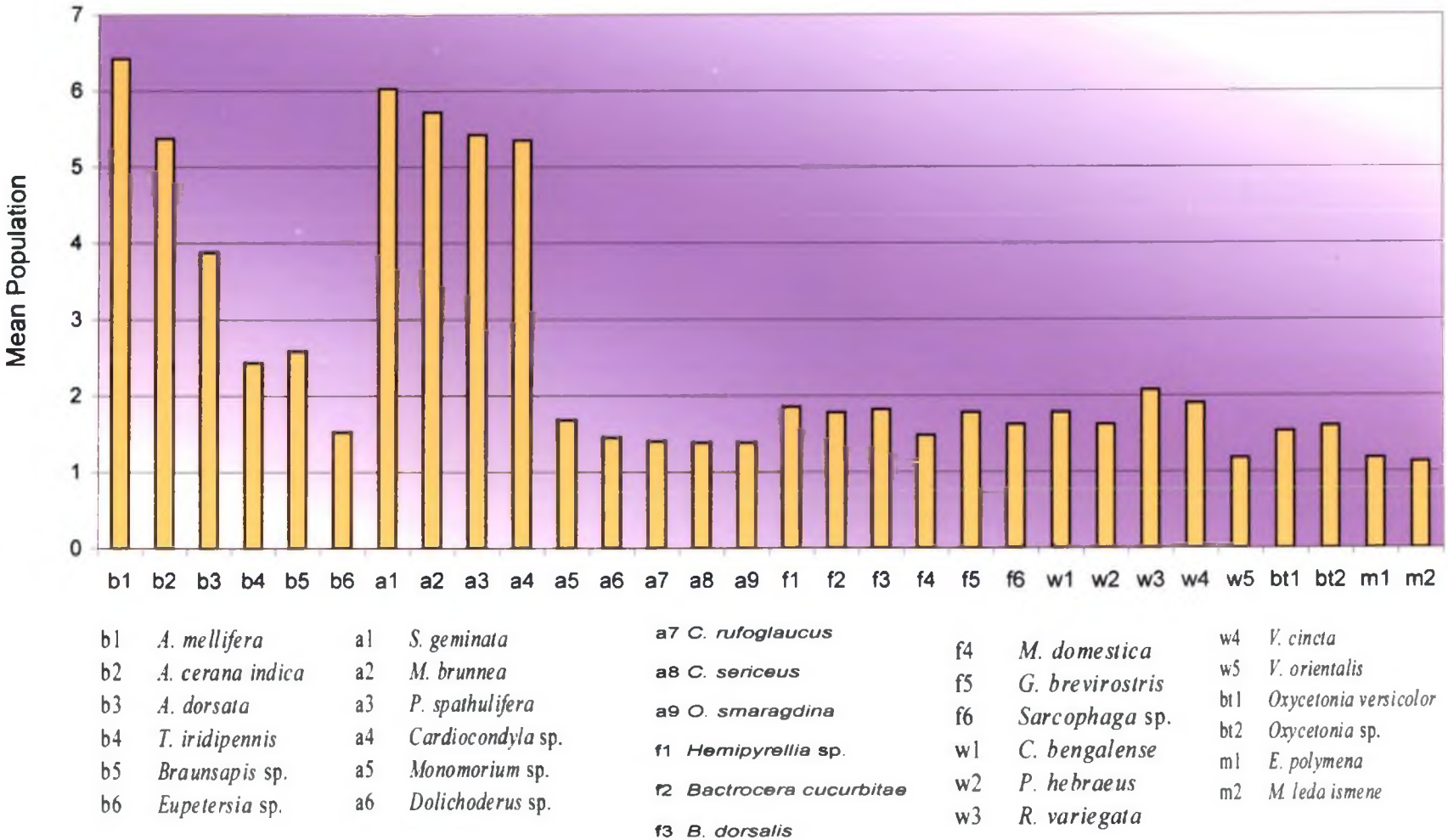


Fig. 5. Population distribution of different insect species recorded over a period of one year

Adlakha and Dhaliwal (1979) showed that the light intensity was responsible for higher bee activity rather than temperature. Bee activity was influenced by temperature and their population was positively correlated with maximum temperature. The findings of the present study was however contradictory to this. Mehrotra and Bisht (1981) was of the opinion that decreased day temperature, rainfall and relative humidity had negative correlation with bee activity and hence reduced bee populations under such conditions. This was in line with the views made by Pande and Bandyopadhyay (1985). Chand *et al.* (1994) had also made similar reports earlier. Although, the visits made by the foragers were not badly affected by weather parameters, minimum temperature, rainfall and relative humidity revealed negative correlations with the number of bee visits to the inflorescence. However, Jeong and Choi (1988) contradicted this by correlating the foraging activity of bees with solar radiation intensity and not with temperature, relative humidity and wind velocity.

While majority of the insect species recorded on the coconut inflorescence, during the period of study, showed positive correlations with maximum temperature, a few insect species *viz.*, *Hemipyrellia* sp., *Musca domestica, Polistes hebraeus, Chalybion bengalense* and *Oxycetonia versicolor* showed negative correlations with it. There was a trend among the recorded insects with reduced or no visits to the coconut inflorescence during rainy periods. Physical environment in itself is a complex of interrelated factors and therefore it is often difficult to separate the influence of individual components. It was therefore apparent that when all weather parameters acted together, it exerts its influence differently on

different foragers. And our knowledge in these aspects is very limited and therefore more research works need to be done.

5.3 RELATIVE SAFETY / TOXICITY OF INSECTICIDES TO HONEYBEES

The assessment of the relative safety/toxicity of different chemical and botanical pesticides under laboratory conditions clearly showed that the botanicals were found to be safer than chemical pesticides to bees. The chemical pesticides caused cent per cent mortality of the bees within two hours of exposure except endosulfan 0.05 per cent which gave 53.33 and 70.00 per cent mortality in various bees. Beevi (2002) suggested that maximum activity of *A. cerana* was observed in palms treated with neem oil garlic emulsion and that low population were observed in dicofol treated palms. Both Azadirachtin 0.004 per cent and neem oil garlic emulsion 2 per cent caused no mortality within 90 minutes of exposure in *A. mellifera* and *A. cerana indica*. However, very low mortality was recorded in case of *T. iridipennis* during this period. Shah (2000) and Beevi (2002) also considered neem oil to be relatively safer and least toxic to bees among various treatments. The findings of the present study also once again confirmed these results. Abrol and Kumar (2000) also supported this by stating neem oil as non-toxic to honeybees. Even 24 h after treatment, both the botanicals have recorded low and comparable mortalities in all the treated bees.

The present investigation also revealed that carbaryl 0.1 per cent to be the most toxic chemical causing high mortalities in all bees within 30 minutes of exposure. Dicofol 0.1 per cent, malathion 0.1 per cent,

quinalphos 0.05 per cent and dimethoate on the other hand took 120 minutes to cause cent per cent mortality in all bees. The results clearly indicate that all the above commonly recommended and used chemicals are highly toxic to honeybees. Graves and Mackensen (1965) and Claudia *et al.* (1970) have reported high toxicities of carbaryl to honeybees. The studies once again confirm the result made by the above authors. Cent percent mortality of all the treated bees was observed within one and half hour after exposure in carbaryl 0.1 per cent. Danka *et al.* (1986), Abrol and Kumar (2000) and Shah (2000) had also reported such high toxicity of carbaryl to bees. However, Hameed *et al.* (1973) have placed carbaryl in the relatively safer group of insecticides under laboratory conditions but considered it to be hazardous when applied under field conditions. The result of the study contradicts this as indicated by high percentage of mortality of bees under laboratory conditions also. Prakash and Kumaraswami (1984) found carbaryl to be moderately toxic in dry film method and relatively more toxic in topical application method. The study however, revealed that carbaryl to be highly toxic to bees even in dry film method.

Dimethoate 0.1 per cent had also caused considerable mortality of bees in 90 minutes after treatment. Palmer-Jones *et al.* (1959) found that dimethoate was highly toxic to honeybees. Nectar of plants sprayed with dimethoate 0.1 per cent was toxic to honeybees was earlier reported by Jaycox (1964). Several other authors (Thakur and Kashyap, 1989; Shah, 2000 and Abrol and Kumar, 2000) have also reported high dimethoate toxicities to honeybees. The results once again warn the indiscriminate application of these chemicals. Indiscriminate use of these chemicals may

completely destroy the honeybee population, which in turn may result in yield reduction in the coconut plantations.

Malathion on the other hand was comparatively less toxic than carbaryl to bees as it caused cent percent mortality in *A. cerana indica* and *A. mellifera* in 120 minutes after treatment. Hasan *et al.* (1986) reported malathion to be least toxic chemical to bees in topical application method. Thakur and Kashyap (1989) and Shah (2000) have also reported less toxic nature of malathion. However, Chandler (1976) had placed malathion in the group of highly toxic chemical to bees under laboratory conditions. The result of the study is however contradictory to this and it may be due to the differences in the formulations of the chemical, age of the treated bees etc. The present study also revealed endosulfan 0.05 per cent to be less toxic than carbaryl, dicofol, dimethoate as it caused cent percent mortality of bees only 12 h after treatment. Hameed *et al.* (1973); Kapil and Lamba (1974); Mishra and Verma (1982); Prakash and Kumaraswami (1984); Sorthia and Chari (1985) and Shah (2000) have also reported endosulfan to be relatively less toxic chemical to honeybees and the present results are in conformity to the above authors.

The results of the present investigation clearly advocate the timely and judicious use of the chemical pesticides in the coconut gardens. Along with it, use of botanical pesticides, which were found to be the safest treatment in the study to the bees, will not only help in the management of pests but also will aid in conserving the bee population which in turn increase the cross-pollination of the crop resulting in an improved quality and quantity of the crop produce.

Summary

6. SUMMARY

There are a large number of insects associated with the coconut inflorescence. A study was conducted to find out the different insect species associated with coconut inflorescence, to determine the occurrence, magnitude and distribution of these insects over a period of one year and to assess the relative safety/toxicity of various pesticides to honeybees. The results of the study are summarized as follows;

Thirty different species belonging to the insect orders Hymenoptera, Diptera, Coleoptera and Lepidoptera were recorded, foraging for either pollen or nectar or both, on the coconut inflorescence.

Hymenopterans formed the most dominant insect order in both male phase (66.67 per cent) and female phase (91.12 per cent). Dipterans represented the next major insect order that visited the inflorescence in male phase (20.00 per cent) and female phase (8.87 per cent) followed by coleopterans and lepidopterans (6.67 per cent each).

The hymenopteran species observed were represented by bees, ants and wasps. Bees included *Apis* spp. (*A. mellifera, A. cerana indica* and *A. dorsata*) along with *Trigona iridipennis, Braunsapis* sp. and *Eupetersia* sp. were found foraging on the coconut flowers.

Foraging activity of *A. mellifera* and *A. cerana indica* peaked during 0900 h followed by a second peak during 1500 h. The lowest activity was observed during 1200 h.

The peak period of activity of *T. iridipennis* was during 1200 h and a second peak during 1800 h.

The different ant species found visiting the coconut flowers were *Solenopsis geminata, Myrmicaria brunnea, Pheidole spathulifera, Cardiocondyla* sp, *Camponotus rufoglaucus, Camponotus sericeus, Monomorium* sp, *Dolichoderus* sp, *and Oecophylla smaragdina.* Of these, *S. geminata, M. brunnea, C. sericeus* and *Dolichoderus* sp. were found as the dominant species during the present study.

The highest foraging activities of ants were observed during 0900 h and the lowest activity was during 1200 h.

Bactrocera cucurbitae, B. dorsalis, Musca domestica, Hemipyrellia sp, *Graptomyza brevirostris* and *Sarcophaga* sp were the six different fly species found associated with the coconut inflorescence. Although, the visits made by them to the inflorescence at different time intervals remained the same, a peak period of activity was recorded during 1500 h.

The present study also revealed the presence of different wasp species *viz., Polistes hebraeus, Chalybion bengalense, Ropalidia variegata, Vespa cincta* and *Vespa* sp. visiting the coconut inflorescence. Low populations of wasps were observed at all the time intervals and were statistically the same.

Two species of beetles *viz., Oxycetonia versicolor* and *Oxycetonia* sp were recorded during the present study and their visits to the inflorescence were more or less similar during the entire period of study.

Apart from all these, two lepidopterans *viz.*, *Euchromia polymena* and *Melanitis leda ismene* were also recorded visiting the coconut inflorescence.

The populations of insect fauna present on the coconut inflorescence were the highest during the 13th day of the male phase. Also, their population on the 12th, 14th and 15th day was statistically same.

In the female phase, highest insect population was recorded on the second day.

Among the different groups of insects present on the male phase of the coconut inflorescence, bees ranked first (20.06) followed by ants (16.67), flies (4.45), wasps (2.23) and beetles (1.98).

In the female phase, the population of ants were maximum (18.04) followed by bees (17.0). Very low population of flies (3.65) and wasps (1.44) were observed during this period.

The occurrence and distribution of different insect species found during the male phase of the coconut inflorescence over a period of one year clearly showed that the population of bees were the highest followed by ants. Low populations of flies, wasps, beetles and moths were also recorded.

The populations of bees were higher in dry months *viz.*, December, January, February, March and April. The populations of bees were lower during the months of May, June, July, August, September, October and November.

Ants showed more or less same pattern of distribution throughout the study period. Flies also exhibited similar population trend during the entire period of study. Not much fluctuation in the populations was observed in case of wasps and beetles.

A. mellifera, A. cerana indica and T. iridipennis showed a strong positive correlation with maximum temperature. *T. iridipennis* also showed a positive correlation with the wind speed. These bees exhibited a negative correlation with relative humidity and rainfall.

M. brunnea showed a significant negative correlation with minimum temperature.*Hemipyrellia* sp. showed a significant negative correlation with wind speed and a strong negative correlation with rainfall.

G. brevirostris showed a significant positive correlation with maximum temperature. *P. hebraeus* and *Oxycetonia* sp. showed a negative correlation with relative humidity and rainfall whereas *C. bengalense* showed a negative correlation with minimum temperature.

All the pesticides recommended for the management of pests of coconut were evaluated under laboratory conditions to study their relative safety/toxicity to honeybees. The results showed that botanicals *viz.,* neemazal and neem oil garlic emulsion were the safest among all the treatments as they caused very low mortality even after 24 h of exposure.

All the tested chemical pesticides were highly toxic to bees. Carbaryl showed the highest toxicity by causing cent percent mortality in 90

minutes of exposure. Dicofol, malathion, quinalphos and dimethoate had caused the same effect in 120 minutes.

Even though, different species of insects were present on the coconut inflorescence throughout the day, the maximum populations were observed during the flower-opening period. Therefore, application of botanicals or timely and judicious use of chemical pesticides will help in reducing pest population at the same time conserve the beneficial insects in the coconut gardens which may eventually increase the pollination of the crop and result in the desired yield enhancement.

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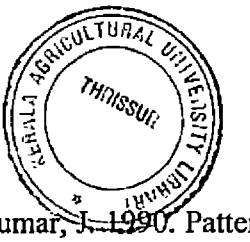

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INSECT FAUNA ON COCONUT (*COCOS NUCIFERA* L.) SPADIX AND EFFECT OF PESTICIDES ON MAJOR POLLINATORS

SHAIJU SIMON

Abstract of the
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Master of Science in Agriculture

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ABSTRACT

An investigation was carried out to document the different insect species visiting the coconut inflorescence, to find out the variations in the foraging activity of different insect species and to assess the relative safety/toxicity of some commonly used pesticides to honeybees.

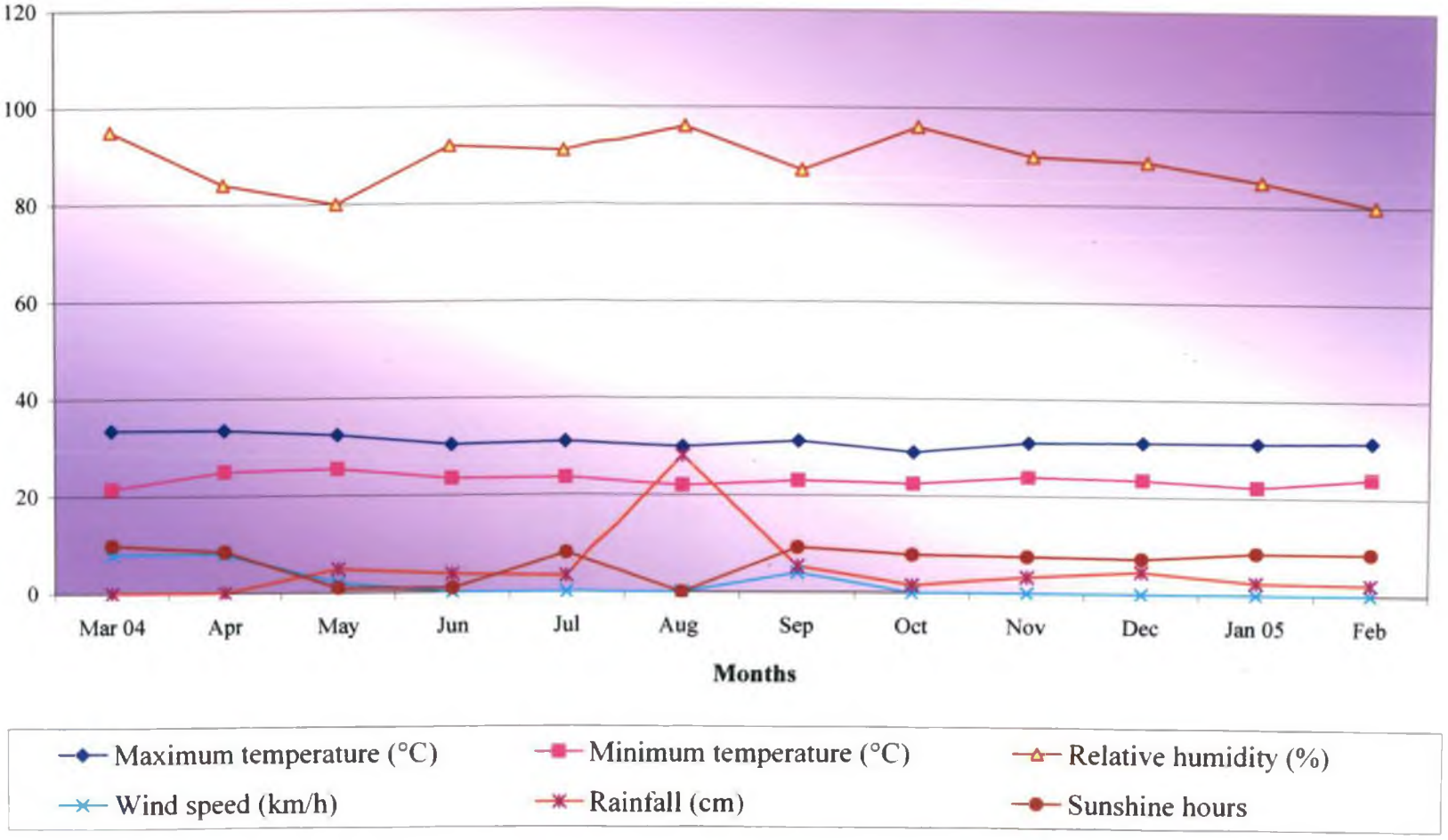
The study revealed that the coconut inflorescence attracted thirty different species of insects towards it. These insect species visited the inflorescence to feed on either pollen or nectar or both. Bees *viz., Apis dorsata, A. mellifera, A. cerana indica, Trigona iridipennis, Braunsa*pis sp and *Eupetersia* sp were found to collect both pollen and nectar of which *A. mellifera* and *A. cerana indica* dominated. Bees were found to forage on the inflorescence throughout the day and exhibit a peak period of activity during 0900 h in case of *A. mellifera* and *A. cerana indica* and during 1200 h in case of *T. iridipennis*. All these species of bees exhibited two distinct peaks during the day of which the second peak was during 1500 h. They mainly collected pollen from half opened male flowers. Ant species that foraged on the coconut inflorescence in large numbers were *Solenopsis geminata, Myrmicaria brunnea, Dolichoderus* sp, *Camponotus sericeus*. They visited the inflorescence for feeding pollen and nectar. The population of ants remained more or less same throughout the day, they visited in higher numbers during 0900 h. They were present on the inflorescence throughout the day and maximum during 0900 h.

Other insect species that visited the palm inflorescence were flies (*Bactrocera cucurbitae, B. dorsalis, Musca domestica, Hemipyrellia* sp., *Graptomyza brevirostris* and *Sarcophaga* sp.), wasps (*Polistes hebraeus, Chalybion bengalense, Ropalidia variegata, Vespa cincta* and *Vespa* sp.), beetles (*Oxycetonia versicolor* and *Oxycetonia* sp.) and moths (*Euchromia polymena* and *Melanitis leda ismene*).

The maximum population of insects was observed on the 13th day of the male phase and in the female phase it was on the second day.

The population fluctuations recorded over a period of one year showed that the occurrence of bees were the highest followed by the population of ants. Bees exhibited a significant positive correlation with maximum temperature and negative correlation with relative humidity and rainfall.

The results on the evaluation of pesticides for their safety/toxicity to different species of honeybees indicated that all the chemical pesticides were toxic to honeybees. Carbaryl 0.1 per cent was the most toxic while endosulfan 0.05 per cent was the least toxic chemical. However, both azadirachtin 0.004 per cent and neem oil garlic emulsion 2.0 per cent were the safest treatments to honeybees under laboratory conditions.



Appendix 1. Weather parameters recorded during the period of study