SEASONAL INCIDENCE OF PREDATORY WASP (*Vespa* spp.) IN INDIAN BEE APIARIES AND EVALUATION OF BAIT TRAPS

by

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(2015-11-017)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"SEASONAL INCIDENCE OF PREDATORY WASP (*Vespa* spp.) IN INDIAN BEE APIARIES AND EVALUATION OF BAIT TRAPS"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS AND SYMBOLS USED

et al.	And other co workers
cm	Centimeter
cm^3	Centimeter cube
CRD	Completely Randomized Block Design
^oC	Degree Celsius
E	East
N	North
Fig.	Figure
g	Gram
m	Meter
mm	Millimeter
hr	Hour
hr^{-1}	Per hour
viz.,	Namely
NS	Non-significant
No.	Number
%	Per cent
RH	Relative Humidity
Sl.	Serial
sp. or spp.	Species (Singular and Plural)
i. e.	That is

APPENDIX

Introduction

1. INRODUCTION

Apiculture is the source of livelihood for many in the world. Besides providing honey and other byproducts like beeswax, pollen and propolis, bees also pollinate crop plants. Beekeeping has been traditionally practiced in India since time immemorial but, with the advent of Khadi and Village Industries Commission (KVIC) in 1957, scientific beekeeping was promoted. The establishment of Central Bee Research and Training Institute (CBTRI) in Pune in 1962, further helped in identifying potential states and rendering extension activities. According to the classification of states based on their potentialities for beekeeping by KVIC, Kerala comes under widely potential states (KVIC, 2017).

Kerala enjoys unique geographical features with rich floral diversity and congenial climatic conditions which offers immense scope for beekeeping in the state. The state has been contributing 70 per cent of the annual production of honey in India, with an average yield of 8030 metric tons in the year 2009-10 (Devanesan *et al.*, 2012). *Apis cerana indica* Fabricius, known as Indian honey bee or Asian hive bee is the most popular honey bee species used for commercial beekeeping in Kerala. Though the industry faced a major setback due to the incidence of Thai Sac Brood Virus (TSBV) in the 90's, the timely interventions of All India Coordinated Research Project on Honey Bees and Pollinators (AICRP HB and P) assisted in its speedy recovery.

Success in the field of beekeeping depends on the technical competence, practical knowledge and proper management of the apiaries. Though, honey bees contribute immensely to the welfare of man through pollination services and honey production, the problems of beekeeping are as diverse as the benefits provided by them.

Honey bees have several enemies that damage the colony or cause serious injury to its comb. Though losses are generally inflicted by the larval forms of wax moths, numerous other insects, arachnids, reptiles, birds and mammals also include bees in their diets, causing considerable injury to the colony. Several

social hymenopterans are reported as pests of honey bees but, predation by hornets or wasps has become a serious threat in Indian bee apiaries nowadays (AICRP, 2013).

The common yellow banded wasps are seen in South Indian plains from June to December. They mainly predate on the foraging worker bees moving in and out of the hive. The predation of honey bees by wasps was observed during the brood rearing season (October-December) and a maximum of 13 wasps hive^{-1}day^{-1} were recorded at the hive entrance during October (AICRP, 2013). The beekeepers at times are compelled to relocate their hives to wasp free areas in order to save their colonies (Chhuneja, 2014).

Most of the paper wasps are efficient pollinators, also feed on known garden pests and hence, are often considered to be beneficial by farmers. As they play a major role in maintaining the biodiversity, it is highly imperative to develop a technique to manage the wasp at hive entrance rather than destroying the entire wasp colony. Studies on the incidence and damage by the wasps in the apiaries as well as the trials to manage them is scanty hitherto. In this context, the present investigation will help in gathering information on the seasonal incidence, predatory potential and methods for managing the predatory wasps in Indian honey bee apiaries.

As an alternative to the burning of wasp nests and disrupting the biodiversity, managing the wasp menace in the apiaries using baits is more preferred.

The information on the pest status of predatory wasp in Kerala is meagre and hence the present study was taken up with the following objectives.

1. To study the seasonal incidence of *Vespa* spp. in Indian honey bee apiaries

2. Assessment of its predatory potential

3. Evaluation of bait traps against the wasp.

Review of literature

2. REVIEW OF LITERATURE

2.1 BEEKEEPING IN INDIA

India is a land of diversified flora with varied climate and ecological conditions and hence, is blessed with four native honey bee species, *Apis cerana indica* Fabricius (Indian honey bee), *A. dorsata* Fabricius (rock bee), *A. florea* Fabricius (little bee) and *Tetragonula (Trigona) irridipenis* Smith (stingless bee). The introduced European honey bee, *A. mellifera* has also successfully spread across the country. In a developing country like India, the role of bees is infinite. Bee keeping is practiced in India since time immemorial and is an integral part of agriculture as it provides economic security to nation and ecological balance to the nature. Besides providing us with honey and other hive products, honey bees pollinate a wide range of agricultural crops and are also used in apitherapy (traditional arthritis cure using bee stings). Traditionally, farmers keep the Indian honey bee *A. cerana indica*, but recently the European honey bee (*A. mellifera*) are also preferred because of its higher honey yield. In Northern region, they are placed in fruit orchards and oilseed crops whereas, in South they occupy rubber (for honey), coffee and coconut plantations (for pollination) (Thomas *et al.*, 2002). It is a source of livelihood of the poor (Kotez, 2013). About 80 per cent of all flowering plant species depends on insects for pollination (Waldbauer, 2017).

India ranks seventh among the honey producing countries of the world since 1991-1992 and exports its produce to more than 62 countries. The quantity exported increased substantially from 8,000 tons in 1998 to 15,587 tons in 2009 (Sharma *et al.*, 2012).

2.1.1 Scope of Apiculture in Kerala

Kerala, the God's own country, literally means 'the land of coconuts', is blessed with the hot spot of biological diversity, the Western Ghats having rich flora and fauna in turn explains the success of apiculture in the state. The beekeeping in this region is based on three seasons *viz.*, honey flow season, lean season and brood rearing season (KAU, 2016). The honey flow season starts with

the bloom of bee flora in January and lasts up to April. It is then followed by the lean season or dearth period (May-August) when the pollen and honey availability are scarce due to the shortage of flowering in plants. The foraging of bees is also reduced due to heavy south-west monsoon showers (Balachandra *et al.*, 2014). During the brood rearing season (September-December), the queen lays more eggs and raise their young ones (brood). It is the season of highest colony population and hive activity.

Thomas *et al.* (2002) reported the practice of intensive migratory bee keeping in the rubber (*Hevea brasiliensis* Muell. Arg) estates and coconut (*Cocos nucifera* L.) plantations of South India. Devanesan *et al.* (2014) listed out 129 plant species among which 60 are nectar (carbohydrate) source, 24 provide pollen (protein), while 45 provide both pollen and nectar. Coconut serves as the main source of both pollen and nectar whereas, the extra floral nectaries of the rubber provides nectar for the nutrition of bees. Nair (2003) reported Kerala as the state producing largest quantity of honey in India. The major honey bee species in Kerala are, *Apis cerana* (Indian honey bee), *A. mellifera* (European bee), *A. dorsata* (rock bee), *A. florea* (little bee) and *Tetragonula (Trigona) irridipenis* (stingless bee) (KAU, 2016). Among these, the Indian honey bee is popularly used for commercial beekeeping in Kerala.

2.1.2 Indian Honey Bee

The Asian region has got the richest honey bee diversity in the world. Among the different honey bee species, the indigenous bee, *A. cerana* and the introduced bee *A. mellifera* are the only domesticated bees for honey production and pollination purpose. Though, European honey bee yield more honey than the Indian bee, people in the rural communities prefer the latter due to its ability to resist pest and diseases (Partap and Verma, 2000). Indian honey bee is reported to have the highest foraging activity (11.40 bees' m^{2-1} min^{-1}), foraging rate (4.77 flowers min^{-1}), foraging speed (5.04 sec $flower^{-1}$) with relatively high abundance during the peak foraging time (1100 hr) (Premila *et al.*, 2014b). With regard to the pollination studies conducted in Kerala, a yield increase of 20, 20-30 and 25

per cent have been reported in cardamom (*Elettaria cardamomum* Maton), coconut (Devanesan *et al.,* 2002) and culinary melon (*Cucumis melo* var. *conomon*) (Premila *et al.*, 2014a) respectively, due to the pollination by Indian bees.

2.2 PESTS OF HONEY BEES

Honey bees are social insects and live in colonies. They rear their young ones and provide them with nutrition (nectar and pollen). For this reason, the bee hives laden with pollen, honey and brood, which serve as a rich source of carbohydrate and protein nutrition for their enemies.

In a study conducted in Karnataka, Swamy (2008) reported 25 species of insect enemies as pests on different species of honey bees, which include bug (*Acanthaspis siva* Distant), wax moths (*Galleria mellonella* Linnaeus and *Achroia grisella* Fabricius), ants (*Camponotus compressus* Fabricius, *Oecophylla smaragdina* Fabricius, *Monomorium* sp.), yellow banded wasp (*Vespa tropica*), robber fly (*Promachus rufipes* Fabricius), dragonfly (*Pantala flavescens* Fabricius), praying mantis (*Mantis religiosa* Linnaeus) and cockroaches (*Periplaneta americana* Linnaeus and *Blatella germanica* Linnaeus) while, Chantawannakul *et al.* (2016), very elaborately reviewed on the pests and pathogens of honey bees in Asia. Mites, viruses, fungi and bacteria were regarded as health stressors of honey bees whereas, the pests included vertebrate pests like bee eating birds and invertebrates like wax moths, small hive beetle, wasps, ants, bee lice, etc.

2.2.1 Report on Pests

As reported by earlier researchers, the pests attacking honey bees may be categorized broadly into two: invertebrates and vertebrates. The invertebrates include insects (wax moths, wasps, ants) and arachnids (mites and spiders) whereas, the vertebrates include reptiles, birds and mammalian pests.

2.2.1.1 Invertebrate Pests

2.2.1.1.1 Wax Moth

El-Niweiri and Satti (2008) observed the incidence of *Galleria mellonella* in the *Apis mellifera* apiaries in Sudan, while in India, it has been reported from Punjab (Brar *et al.*, 1985; Brar *et al.*, 1992a; Brar *et al.*, 1996; Deosi *et al.*, 2014), Jammu and Kashmir (Abrol and Kakroo, 1996), Uttarakhand (Varshneya *et al.*, 2008), Assam (Deka *et al.*, 2010), Uttar Pradesh (Vishwakarma *et al.,* 2012) and Odisha (Mishra *et al.*, 2009a; Satapathy and Mohapatra, 2015).

The life cycle of wax moths has been studied by numerous workers. The female moths lay eggs in the cracks and crevices of the hive which are barely detected by the worker bees (Brar *et al.*, 1992b). The emerging larvae are creamy white in colour whereas, later instars are grey coloured. The pupae rest in white coloured cocoons (Mishra *et al.,* 2009b). They are the largest comb infesting Lepidopteran larvae.

According to Williams (1978), in India, the wax moth infested bee colony absconds when the attack is fierce during monsoon period. In Punjab, Brar *et al.* (1992b) reported the incidence during the dearth period (June-September). According to the study by Varshneya *et al.* (2008), the seasonal incidence of wax moth started from July and reached its peak in September. He also inferred that the poor weather conditions and lack of bee flora aggravated the condition. Studies in Assam revealed the infestation by wax moths prevalent throughout the year at different intensities (Deka *et al.,* 2010). Vishwakarma *et al.* (2012) also stated its incidence from June - September in the *A. mellifera* colonies of Uttar Pradesh.

The damage due to wax moth has been reported at various intensities from different parts of the world. In Sudan the damage was 64.50 per cent (El-Niweiri and Satti, 2008) whereas, in Assam, an infestation of 44.44 per cent was noticed in September for which use of *Bt* formulation (0.5 g L^{-1} $hive^{-1}$) was suggested as a method of control (Deka *et al.,* 2010).

2.2.1.1.2 Wasps

The common yellow banded wasp, *Vespa cincta* F. (Hymenoptera: Vespidae) was reported as a predator of Indian honey bee by Ramachandran (1952). In India, *V. orientalis* has been reported from Punjab (Brar *et al.*, 1985; Chhuneja *et al.,* 2008 and Chhuneja, 2014) and Himachal Pradesh (Sharma *et al.*, 1985; Mishra *et al.*, 1989), *V. orientalis* and *V. tropica* from Uttarakhand (Varshneya *et al.*, 2009), *V. velutina* from Jammu and Kashmir (Abrol, 1994) and *V. magnifica* from Assam (Rahman and Rahman, 1995; Rahman *et al.*, 2001; Deka *et al.*, 2015). The predatory attacks of the greater banded hornet, *Vespa tropica* on forager bees in and around the hives have been earlier reported by various workers (Burget and Akratanakul, 1982; Gulati and Kaushik, 2004; Munawar and Camphor, 2009; Ranabhat and Tamrakar, 2008; Swamy, 2008; Varshneya *et al.*, 2009; Bhatta and Tamrakar, 2011; Sharma *et al.*, 2013; Sharma and Mattu, 2014; Islam *et al.*, 2015).

2.2.1.1.3 Ants

Swamy (2008) observed weaver ant or green ant, *Oecophylla smaragdina* Fabricius and common godzilla ant, *Camponotus* sp. as pests of honey bees in Karnataka. The damage due to ants was reported to be 95.70 per cent in the bee colonies of Sudan (El-Niweiri and Satti, 2008). Yang *et al.* (2010) in Africa mentioned the nuisance by the tramp ants (*Pheidole megacephala* Fabricius) that move fast and imbibe honey from the hives. The ants also bit the legs of bees and often killed weak bees. Vishwakarma *et al.* (2012) too reported *O. smaragdina* as a pest of European honey bee with an incidence of 210.66 ants $hive^{-1}hour^{-1}$ during the 17^{th} standard week of the year.

2.2.1.1.4 Spiders

The spider species reported as bee predators vary widely. The spider *Nephila kuhlii* Doleschall has been reported as bee hunter in Nepal throughout the year (Pokhrel *et al.*, 2006). El- Niweiri and Satti (2008) indicated the presence of Salticids and Thomisids in the *A. mellifera* hives in Sudan and the loss due to

them was 2.20 per cent while, the findings of Kinati *et al.* (2012) revealed spiders as a threat to 1.90 per cent beekeepers of Ethiopia. Sharma *et al.* (2013) spotted two spiders' *viz.*, *Sparssus* sp. and *Paradosa* sp. in the bee hives of Himachal Pradesh. Studies in Kerala by Jayalekshmi (2015) revealed two tailed spider, *Hersilia savigyni* Lucas and white crab spider, *Thomisus lobosus* Tikader as pests of stingless bees. Regarding the occurrence of spiders, Vaibhav *et al.* (2017) opined that giant cross spider, *Argiope anasuja* Thorell was common during summer and monsoon season, *H. savigyni* during summer and winter months and *T. lobosus* during summer, winter and monsoon season.

2.2.1.1.5 Mites

Investigations by Hameed and Singh (1989) in Indian bee colonies revealed 66.90 per cent loss in honey production due to mite infestation. The mite was reported to infest pupal broods and thereby resulted in deformed winged adults (Hameed and Singh, 1992).

Hosamani *et al.* (2005) reported maximum incidence (7.50 per cent) of ectoparasitic mite (*Tropilaelaps clareae*) on *A. mellifera* colonies of Hisar during April-May. Brood was much preferred by the mites than adults. The incidence of *Varroa destructor* ranged from 0-16 per cent (Asha *et al.,* 2010).

2.2.1.2 Vertebrate Pests

2.2.1.2.1 Lizard

In Nepal, Pokhrel *et al.* (2006) noticed *Hemidactylus flaviviridis* Ruppell as the predator of bees while, small geckos (*H. fasciatus* and *H. brooki*) were reported as frequent visitors of bee colony in Nigeria (Lawal and Banjo, 2007). According to Sarwar (2016), *Calotes* spp., *Acanthosaura* spp., *Sphenomorphus* spp. and *H. frenatus*, often act as pests of honey bees. They hide in the empty space between the rain shelter sheet and top cover of the hive and predate on bees.

2.2.1.2.2 Honey buzzard

Honey buzzard has been reported as honey bee pests in several studies. Despite of the name honey buzzard, the main diet of these birds apart from bees,

consists of social wasps too (Birkhead, 1974). The oriental honey buzzard (*Pernis* sp.) has been stated as specialists predators of honey bees by Oldroyd and Nanork (2009). In his study on the status and distribution of raptors in Wayanad, Kerala, Kurup (2011) found *P. ptilorhynchus* from March-May, coinciding with the availability of honey. Basavarajappa and Raghunandan (2013) also has reported its incidence from Karnataka.

2.2.1.2.3 Monkey

Monkey has been reported as pests in the Mangrove apiaries where, they start up this by smearing each other with red clay or mud in order to avoid the bee stings (Krishnamurthy, 1990). The clay coat is removed after the completion of the work. They also poke a twig into the honey comb and lick on the honey coated on it. Monkeys were also reported as pest in the beekeeping areas of the south west Ethiopia (Kinati *et al.,* 2012) and Sundarbans (Sohela, 2013). They raid and shatter the hives in the apiary in search of food.

2.3 PREDATORY WASPS

Predatory wasps are very strong and active and grasp on bees, flies, caterpillars, moths, butterflies and even other wasps. They not only destroy the bee population in the apiaries by predation, but also do harm to man by their painful poisonous sting. Moreover, the plantation workers' often find it difficult to harvest the crop due to the presence of wasp nest in the bushes. Attracted by the volatiles from ripe fruits, they also tend to damage the fruits of papaya, guava, grapes, apple, etc. They usually forage for water, pulp, carbohydrates and animal protein (Matsuura and Sakagami, 1973) but may also be attracted to the meat flesh (Arke and Davis, 1978). They attack honey bee colonies to feed their brood with proteins, and to get carbohydrates (honey) to maintain their energy levels (Rortais, 2010).

2.3.1 Morphology

The species *Vespa tropica* has eight subspecies of which *V. tropica. haematodes* occupy the Indian subcontinent (Archer, 1991). The species is large,

black and fuscous, characterized by reddish marking on head and thorax with first gastral segment black and second gastral segment orange or orange yellow (Bequaert, 2016).

2.3.2 Biology

The studies on the biology of *V. tropica* are scarce. However, Archer (1991) had stated the mean developmental period of a worker wasp as 35-36 days (eggs 6 days, larvae 12-13 days, sealed brood 17 days).

2.3.3 Life Cycle

The life cycle of wasps consist of a pre-nesting period (April) during which the workers and inseminated queen enter hibernation. The solitary phase begins in late April, when the queen searches for nesting site, feeds on tree sap and rears about 40 workers which emerge in early July. From mid-July, as the worker population increases the queens stop leaving nests. Later, in August the nests are well developed and male eggs are laid. The males emerge in mid-September. After mid-September, eggs of sexuals are laid which emerge as adults in mid-October. During this time the foraging habit changes from animal (protein) food to carbohydrate diet (Bequaret, 2016).

2.3.4 Nesting

Most of the *Vespa* spp. prefers hilly forest regions as their nesting sites. The nests of these wasps are large, pear shaped, broad below and tapering towards upper end, built using plant fibers and can be seen on the branches or cracks of trees and bushes, roofs of houses or even below ground. It consists of brood cell containing combs covered by a sheet of papery envelope (Bequaert, 2016).

2.3.5 Habitat

In a study conducted in Pakistan in 2004, Munawar and Camphor (2009) observed that *V. orientalis* was restricted to plains and dry rainfed areas whereas, *V. velutina, V. basalis, V. tropica* and *V. vulgaris* were abundant in hilly areas

with moist and humid conditions. Apiaries situated near the foothills and tropical forests suffer more acutely than those on the plains (NBB, 2016).

2.3.6 Species

The genus *Vespa* (true hornets) has 23 species, and are mostly distributed throughout eastern Asia. Asian giant hornet, *V. mandarinia* is reported from Himalayan ranges and is the largest (42 mm in length) wasp species in the world. While greater banded hornet, *V. tropica* is found throughout India, including Andaman & Nicobar Islands, lesser banded hornet, *V. affinis* is most common and widely distributed only throughout India. However, Oriental hornet, *V. orientalis* occur in Indo-Gangetic plains in human inhabited areas, and is attracted to sweets and gur. Yellow legged hornet, *V. velutina* is found in Eastern Himalaya and is less common in India (Matsuura, 1991).

2.3.7 Occurrence and Distribution

Predatory wasps belonging to the genus *Vespa* are serious pests in the apiaries. According to Arke and Davis (1978), the species of the genus is mainly found in eastern Asia. Due to the paramount diversity and presence of a vast number of species, southern regions of China and eastern Himalayas are perhaps considered as the center of origin of *Vespa*. Among different *Vespa* species, *V. orientalis* and *V. crabro* are seen in the western Palearctic region whereas, *V. basalis, V. mocsaryana, V. multimaculata* and *V. bellicose* occupy the forests of the Oriental region. *V. affinis, V. analis, V. tropica* and *V. velutina* nests in the densely colonized forest cleared areas. They are not yet reported from Australia (Bequaert, 2016).

2.4 SEASONAL OCCURRENCE

2.4.1 Incidence of Predatory Wasps

While studying on *Vespa cincta* as a predator of honey bees, Subbiah and Mahadevan (1957) reported its attack during the periods of low breeding activity (June-December) at Coimbatore, thus leading to weakening and perishing of the

colony. In Solan, the wasps were observed in the apiary during September and a maximum of seven wasps per day was recorded in October (Kumar *et al.*, 1998). According to Swamy (2008), in Karnataka the adults of the yellow banded wasp, *V. tropica* were observed predating on the *Apis mellifera* and *A. cerana* adults during June to September. Though the attacks by wasps *V. velutina, V. bicolor, V. tropica* and *V. basalis* is seen throughout the year in Nepal, predatory raids mostly occur from the months of July to September which eventually coincides with the floral dearth period (Ranabhat and Tamrakar, 2008).

Studies on seasonal incidence of predatory wasps in the European bee colonies in Pantnagar, Uttarakhand showed the presence of two *Vespa* species- *V. tropica haematoides* and *V. orientalis*. The attack of the former on the colony was more severe compared to the latter and about 42-60 wasps were observed in the apiary during the month of September. The attack was nil during the winter and spring months from January to May. The wasps started appearing towards the end of June and fierce attack was seen during the rainy season (July to September). In autumn season, maximum population was recorded in October which gradually decreased to the end of December (Varshneya *et al.*, 2009).

The wasp (*Vespa orientalis*) incidence in Uttar Pradesh, coincided with the floral dearth period. Though the wasps were seen from May to October, the predation was observed from July to September. A maximum of 6.80 wasp day^{-1} during the 30th standard week and the minimum (1.09 wasp day^{-1}) was observed in the 43rd week (Vishwakarma *et al.*, 2012).

Studies in Odisha revealed an average of 2.50 large black wasps (*Vespa magnifica*) visit in each European bee hive day^{-1} (Mohapatra and Sontakke, 2013). The incidence of six *Vespa* spp. *viz., V. auraria, V. mandarina, V. tropica, V. orientalis, V. basalis* and *V. flaviceps* has been reported during August-November from bee hives in Himachal Pradesh (Sharma *et al.,* 2013; Sharma and Mattu, 2014).

While examining the European bee apiaries of Punjab, Chhuneja (2014) observed the yellow banded brown predatory wasp, *V. orientalis* as a serious pest from July to December. The wasp was occasionally seen during June but was rare during January to May. The mean daily population of wasp during different months ranged from 2-14 in July, 6-12 in August, 0-19 in September, 6-15 in October and 0-6 in November. The population of wasp was negligible in December.

The peak incidence of hornet (*V. orientalis*) in Egypt was observed in the month of October (9.6 wasps colony^{-1} 3 minute^{-1}), followed by September, November and December. However, the predation was maximum during September (1.12 bees colony^{-1} 3 minute^{-1}). Thus, the mean number of bees preyed during September was 4752 (Abd Al-Fattah *et al.*, 2014).

Experiments conducted in the year 2011-12 and 2012-13 in Himachal Pradesh, showed the maximum visits by the wasps in September with *V. auraria* visiting 83 and 81 times and *V. mandarina* visiting 11 and 15 times, respectively (Sharma and Mattu, 2014). Abdelaal and El-dewafrey, (2014) recorded highest incidence of *V .orientalis* in September - October in Egypt while, Taha (2014) noticed the incidence of queen wasps from January to May and the workers from June to February. The peak incidence was in October (156.25 hornets).

The wasps were observed from the start of May to the end of December in Pakistan,, with the population reaching its peak during August, September and October (Munawar and Camphor, 2009). Islam *et al.* (2015) observed a low population of *V. velutina* and *V. orientalis* in June whereas, *V. tropica* were seen only at the start of July. The populations gradually increased to reach its peak in October and then decreased towards the end of November. The highest number of wasps (*V. velutina*) recorded an increase from 158 wasp week^{-1} in August to 532 wasps week^{-1} in September and 683 wasps week^{-1} in October. A maximum of 833 and 220 hornets (*V. velutina* and *V. orientalis*) week^{-1} was observed in October.

2.4.2 Peak Hour of Wasp Incidence

Brar *et al.* (1985) in Punjab reported peak population of wasps during mid-day hours of the day (1200-1400 hr). In Nepal, Ranabhat and Tamrakar (2008) observed the peak interval of wasp attack in the early hours of morning (0700-0900 hr) and in the noon (1200-1400 hr). The frequency of wasp attack was least observed during cloudy and rainy conditions. According to Varshneya *et al.* (2009), the peak time of wasp attack in the *Apis mellifera* colonies of Pantnagar, Uttarakhand was at the mid-day hours from 1200-1600 hr. Though the wasps visits the apiaries from 0600-1400 hr of the day, Vishwakarma *et al.* (2012) cited morning hours of the day as peak time of attack. In Egypt, Abd Al-Fattah *et al.* (2014), found the highest incidence of hornet (*V. orientalis*) attack from 1300-1600 hr (7.20 hornet colony^{-1} 3 minute^{-1}), followed by 6.80 hornet colony^{-1} 3 minute^{-1} from 1000-1300 hours and 5.50 hornet colony^{-1} 3 minute^{-1} from 0700-1000 hr. According to Chhuneja (2014), in Punjab, the wasp incidences in the apiaries were higher at noon compared to the morning and evening hours. Islam *et al.* (2015) recorded 0800-1100 hr and 1500-1800 hr as the peak foraging hours of the wasp in the European bee apiaries of Pakistan.

2.4.3 Correlation Studies with Weather Data

Studies conducted in Punjab on the population dynamics of *V. orientalis* in European bee apiaries by Chhuneja *et al.* (2008) observed a positive correlation between the mean daily total wasp populations and mean maximum and minimum temperatures, mean daily temperature and mean relative humidity. They also observed that the higher wasp population in the year 2007 was due to the higher relative humidity compared to the previous year. Varshneya *et al.* (2009) also observed a positive correlation of wasp population with minimum temperature, minimum and maximum relative humidity. They too found the wasp attacks more in the colonies with more number of hives, hence showing a positive correlation. Similarly, Sharma and Mattu (2014) observed a positive correlation of temperature and relative humidity with the wasp incidence. In Egypt, Taha

(2014) observed a significant positive correlation between the *Vespa orientalis* population and the temperature and relative humidity.

The average temperature and relative humidity recorded in October (peak occurrence of wasps) in the apiaries was 29.11°C and 68.82 per cent. In August and September, the temperature noted was 32.86 °C and 33.04 °C whereas, the relative humidity documented was 78.93 and 68.09 per cent, respectively (Islam *et al.*, 2015). The weekly number of wasps showed a negative relation with temperature and a positive relation with humidity.

2.5 PREDATORY POTENTIAL OF WASP

According to Matsuura and Sakagami (1973), in Japan, the absence of beekeepers for even one hour can result in the loss of colony. The predation on bees by 20-30 hornets for one-six hours in the apiary can lead to a loss of about 5,000 to 25,000 bees. From this, they concluded that each hornet killed approximately one bee at every 14 seconds.

Koeniger *et al.* (1996) concluded that a single worker of *V. multimaculata* could predate on 14 bees in 12 hour period whereas, Ranabhat and Tamrakar (2008) reported the predatory potential of wasps as 1.25-12.25 bees day^{-1} during the floral dearth period (July- September). Munawar and Camphor (2009) in Pakistan reported the predation of 10 bees and 5.8 bees day^{-1} by *V. orientalis* and *V. tropica,* respectively. The number of captures increased with the number of chasing hornets, reaching a maximum when 9 hornets $hive^{-1}$ were observed (Monceau *et al.*, 2013). Abd Al-Fattah *et al.* (2014) stated a mean loss of 2.39 bees $colony^{-1}$ 3 $minute^{-1}$ due to *V. orientalis* attack in the *Apis mellifera* apiaries of Egypt.

The wasp *V. orientalis* killed about 33 honey bees day^{-1} in Israel. When the adults of *V. mandarinia* come in group (30 adults at a time), about 25,000 honey bees were killed in just three hours. While, the bees could defend themselves by killing just two wasps only (Matsuura and Sakagami, 1973).

Survey conducted in 2011-12 in different districts of Karnataka revealed that along with other factors, wasp menace cause an absconding of 67.50 per cent of *Apis cerana* colonies (Pradeepa and Bhat, 2014).

2.6 MODE OF ATTACK BY WASP

A four day study on the predation of bees by the bee killer wasp, *V. tropica* in the *Apis mellifera* hives in Thailand revealed that the number of wasps was low during the initial hunting phase but later, the number increased to about 40 during the slaughter phase. The hornets seized and crushed the bees due to which the bees absconded. The wasps later spent more time inside the hive to prey on the bee brood and also consumed the stored honey (Burgett and Akratanakul, 1982). Insects and spiders serve as the main protein sources for hornets (Matsuura, 1991)

The predatory nature of wasps as observed by Koeniger *et al.* (1996) presented a hovering phase for about 30 sec, wherein the wasps prevented the entry of returning forager bee into the hive and also spread their legs to grasp them. After pouncing on bees, they displayed a downward motion and then soared upward to land upon a tree branch, where they detached the bees head and carried the remaining portion to their nest.

Attracted to the strong scent of honey and pollen, the wasps arrive at a bee hive and hover near the hive entrance to grab on a single bee. The persistent wasps pounce on the bees at great ease when they are isolated rather than when they form a cluster. The wasps then move to a nearby perch where it processes its prey by biting off its wing and abdomen. The thorax was then taken to the nest as food for the brood. As a result of continuous attack, the colony absconded and the hornets devoured on the brood by remaining inside the hive (Glaiim, 2009).

Most time they spent chasing returning forager bees and hovering near the hives where the bees caught increased during midday. Monceau *et al.* (2013) reported that the forger honey bees are more prone to predation by *V. velutina* because of the heavy pollen and nectar loads they carry which reduce their

efficiency of flight. They also opined that the damaged wing of the foragers which are the older individuals of the colony may also influence their flight pattern.

In the laboratory study, Couto *et al.* (2014), found that the *V. velutina* use their sense of olfaction to locate their food source. Increased attraction was shown towards pollen, honey and a honey bee aggregation pheromone (geraniol) while products like wax, propolis, adult honey bee, larva, minced beef, fish and wet paper failed to attract the wasps. Thus, they concluded that the hornets detect the bee hives by their sense of olfaction.

2.7 DEFENSE MECHANISM OF HONEY BEES

In the much evolved, social insects like honey bees, defense behaviour against its enemies is well organized. When a wasp persists in attack, several worker bees engulf it in a ball and kill it by raising their thoracic temperature (Matsuura and Sakagami, 1973). A study on defensive behaviour was conducted by Sharma *et al.* (1979) where, in a colony, when an injured wasp was put at the entrance the wasp visits were found to be decreased. According to the study conducted by Koeniger *et al.* (1996), on confronting with the wasps, the honey bee, *Apis nuluensis* exhibited oscillating body movements, clustering and balling behaviour to kill their enemy. During balling, endothermic heat is generated by the thoracic musculature (Esch and Goller, 1991).

Experiments conducted by Ken *et al.* (2005) determined the lethal temperature of wasps and bees. They placed ten each of *A. cerana, A. mellifera* and *V. velutina* in an incubator and gradually raised the temperature from 42 °C to 52 °C. The lethal thermal limits obtained was 45.70 ± 0.48 °C for *V. velutina* and 50.70 ± 0.48 °C and 51.80 ± 0.42 °C for *A. cerana* and *A. mellifera*, respectively. They also concluded that the foraging of *A. cerana* was significantly reduced in the presence of wasps. The typical smell of iso-pentyl acetate, a major alarm pheromone component in *Apis*, from the balling bees revealed that the reduction in foraging is induced by olfactory cues. During wasp attacks at the hives, the

numbers of bees foraging were significantly reduced with increased wasp attack time. The longer the duration of wasp exposure to *A. cerana*, the longer the recovery time to initial foraging levels.

Abrol (2006) observed balling behaviour in *Apis cerana* bees as defense mechanism against predatory wasps *V. velutina* and *V. maganifica* in Jammu and Kashmir. Out of 11-35 wasp visits in 2 hours, the bees could capture and kill 3-5 wasps 2 hours^{-1} by increasing their thoracic temperature to about 45-46 °C which is lethal to the wasps but not the bees.

The wasps' hawk (capture) foraging honey bees on the wing near honey bee colonies, and predation is especially fierce in autumn when *V. velutina* are most populous. While native *A. cerana* colonies have evolved defense strategies against wasp predation, the introduced *A. mellifera* sustains significantly greater losses than the former. When the wasps come close to a honey bee nest, the guard bee cohort increases, shimmers their wings and if the attack persists, the guard bees launch strikes to kill them by heat-balling (Tan *et al.*, 2007).

When vespine wasps, *V. velutina* hawk (capture) bees at their nest entrances, alerted and poised guard bees have average thoracic temperatures slightly above 24 °C. Many additional worker bees of *A. cerana* are recruited to augment the guard bee cohort and begin wing-shimmering which raises the average thoracic temperature to 29.8 ± 1.6 °C. When the wasps persist hawking, about 30 guard bees that has raised their thoracic temperatures to 31.4 ± 0.9 °C strike out at a wasp and form a ball around it. Within about three minutes the core temperature of the heat-ball of bees reaches about 46 °C, which is above the lethal limit of the wasps, which are therefore killed (Tan *et al.*, 2010).

2.8 METHODS FOR MANAGING WASPS

2.8.1 Destruction of Wasp Nests

Subbiah and Mahadevan (1957) suggested several methods for managing the wasps which includes fumigation of their nest using calcium cyanide (if the nests are accessible) resulting in complete mortality, capturing using nets and

destruction, spraying 0.05 per cent parathion towards the nest after sunset, decreasing space in front of the base board prevents the alighting and hence, the attack by wasps. Islam *et al.* (2015) opined destruction of hornets' nest by burning as an effective way to reduce hornet population in the European bee apiaries of Pakistan while, Deka *et al.* (2015) has reported 73-85 per cent control can be obtained by burning the nests of hornets.

2.8.2 Use of Barriers at Hive Entrance

Rahman *et al.* (2001) reported a reduction in the predation of European bees by *Vespa magnifica* wasps by the use of 1 cm mesh size nylon net as a barrier. The queen excluder at the hive entrance prevented the hornets from entering into the hive to catch bees, but served as a resting place for the wasps to prey upon the bees. Also, the queen excluder acted as a hindrance for the free movement of bees as a result of which they were easily preyed by the wasps (Glaiim *et al.*, 2008). They also tried the use of a wire gauze cone which was later replaced by a cardboard cone to prevent the damage done to the bees by the wasps. Though the cardboard cone reduced the wasp entry to the hive, it affected the free ventilation as a result of which there was a drastic reduction in the adult bee population. In Egypt, Abd Al-Fattah *et al.* (2014) found that the use of queen excluder was effective against *V. orientalis* attack. Compared to control (with no queen excluder) the use of queen excluder could reduce the mean number of bees preyed from 2.39 bees colony^{-1} 3 minutes^{-1} to 0.27 bees colony^{-1} 3 minutes^{-1}. Thus, queen excluder was found efficient in reducing hornet attack. According to Deka *et al.* (2015) wire gauge screening gave 70-75 per cent control over the predation of bees by *V. magnifica*.

2.8.3 Different Types of Traps

Bacandristos *et al.* (2006) evaluated the efficiency of three insecticide free traps for the control of bee predating wasps and found that compared to plastic bottle trap and double chamber trap, wood glue trap provided better results. The evaluation of different traps (wooden plastic bottle trap and iron wire gauze net

trap) for the control of wasp populations in the *Apis mellifera* apiaries of Pakistan by Islam *et al.* (2015) found that the wooden plastic bottle trap along with honey bait was effective in controlling the wasp when placed on the top of the Langstroth modern hive.

2.8.3.1 Attractiveness of Wasps to Bait

Sharma *et al.* (1979), studied the relative attractiveness of different baits to *V. auraria* where the untreated meat showed 100 per cent "attractancy", while the meat + 0.25 per cent trichlorfon had 59 per cent and with 0.5 per cent trichlorfon alone had 20 per cent attractancy. Evaluation of baits against the wasps revealed that three *Vespa* species preferred decaying fish to decaying meat while *V. basalis* preferred rotten apples.

Yellow jackets (*Vespula* sp.), in the U.S. and Europe, were found to prey on live or dead adult bees, steal honey also. Control of these social wasps is difficult as the nest must be found before the population can be eliminated with an insecticide. However, baiting yellow jackets with or without insecticides can be quite successful (Mayer *et al.*, 1987). The management of wasps using over ripe pear fruits as poisoned (Fenitrothion) baits, 'capsule cup' technique of loading poisoned bait in a cup attached to the thorax of wasp were found to destroy the nest of the wasp (Mishra *et al.*, 1989).

Evaluation of bait traps by Rahman and Rahman (1995) against *V. magnifica* [*V. mandarinia*], a predator of the honey bee (*Apis mellifera*), around hives at Jorhat, Assam revealed that baits consisting of fermented pineapple and molasses (4:1) is effective. Most of the wasps were found trapped early in the trapping season and the intensity of incidence was reduced considerably in the subsequent weeks.

Studies conducted by Spurr (1995) on a number of protein baits in New Zealand revealed that fresh fish and meat were the most attractive baits to wasps. The wasps also collected preserved sardine food to their nests and hence, were considered as the best bait for trapping wasps. The other baits trialed included

cooked meat, fish oils, fish and meat volatiles, etc. Spurr (1996) also found that compared to honey, jams, gels and other viscous and solid carbohydrates, wasps preferred 30 per cent sucrose solution as it was more volatile and unlike protein baits it need not be torn or chewed.

Studies in Himachal Pradesh, India, showed that bait traps containing sucrose or fermented honey, followed by traps containing an insecticidal bait (Baygon [Propoxur]) were effective in protecting *A. cerana* against predation by *Vespa magnifica* [*V. mandarinia magnifica*] (Thakur and Kashyap, 1996).

Bacandristos *et al.* (2006) tried two protein baits against bee eating wasps-fresh sardine fish and fresh beef bait. According to them, fish bait trapped more wasps. Also, the baits had more result when placed in morning hours (0800 hr) with constant replacement at 1-2 days interval (to avoid drying and decomposition of baits). According to them, the lower wind speed during morning hours facilitated easy flight and search for the wasps.

Dvo (2007) suggested the use of beer baits for trapping the vespine wasps in the forest ecosystems of Europe. Glaiim *et al.* (2008) cited that vinegar trap made of dates not only failed to attract the wasps but also caused harm by trapping the bees. Bhatta and Tamrakar (2011) reported that the rotten fish and pear baits, when replaced weekly trapped the highest number of hornets, with the least number of foraging honey bees. The wasps are attracted to some olfactory stimulants like volatile oils of cinnamon and camphor and mint and banana. Fermented grape juice and chicken litter also attracted wasps (Abd El-Kareim *et al.*, 2013).

Based on the studies conducted in Italy, Demichelis *et al.* (2014) found that the beer bait trap in clear and transparent polyethylene bottles with a yellow cap attracts *Vespa velutina* wasps. Compared to grapes, honey attracted more wasps when placed in the fields during morning hours and replaced daily (Islam *et al.*, 2015).

2.8.3.2 Trap Placement in the Field

While studying on the traps againsts wasps in Greece, Bacandristsos *et al.* (2006) emphasized on time of placement of baits in the apiary. They suggested the morning hours of the day as best for the placement of fresh baits and that it be replaced every 1-2 days (to avoid decomposition). Islam *et al.* (2015) opted to place the bait traps randomly on the top of the European bee hive.

2.8.3.3 Wasps and Other Insects Caught in Traps

According to Bacandritsos *et al.* (2006), a total of 11,122 adult *V. orientalis* was trapped in the fish and beef traps set in the apiaries during the four year period from 2001-2004. Other vespines trapped included *Vespula germanica* (3530 Nos.). They also found some other insects trapped in protein based trap which included, ants and dipterans. Bhatta and Tamrakar (2011) reported honey bees trapped in rotten fish and pear trap.

2.8.4 Flapping

According to Sharma *et al.* (1979), the use of a wooden flapper for 30 minutes in the apiary reduced the number of wasps for the following three hours. In Assam, flapping reduced the predatory wasps in the apiaries by 58.00 -73.55 per cent (Deka *et al.*, 2015).

Materials and methods

3. MATERIALS AND METHODS

The study entitled "Seasonal incidence of predatory wasp (*Vespa* spp.) in Indian bee apiaries and evaluation of bait traps" was carried out in the Department of Agricultural Entomology, College of Agriculture, Vellayani during 2015-17. The study was conducted to assess the seasonal incidence of predatory wasp in the purposively selected Indian bee apiaries of AICRP (HB and P), Vellayani centre and also to evaluate bait traps against them.

Beekeeping in Kerala is done on the basis of three seasons- lean season, brood rearing season and honey flow season. Lean season (May-August) or dearth period is the period of acute food scarcity as the bees mostly remain confined to the hives due to the heavy south-west monsoon showers. During the brood rearing season (September-October), the bees raise their young ones (brood) contributing to the colony strength. Honey flow season (January-April) is the period of surplus nectar availability, especially from the extrafloral nectaries of the rubber (KAU, 2016).

3.1 DOCUMENTATION OF PESTS OF HONEY BEES

3.1.1 Selection of Location

The study was conducted in the purposively selected Indian bee apiaries (*Apis cerana indica* Fabricius) of AICRP (HB and P), Vellayani centre. The geographic details of the location/ apiaries are mentioned in Table 1. The locations were selected based on the previous years' AICRP reports on wasp incidences in these apiaries.

Ten apiaries having a minimum of ten hives per apiary were selected (five apiaries at Nedumangad (Plate 1a), three apiaries at Vilappilshala (Plate 1b) and one apiary each from Balaramapuram and Vellayani). The apiaries were named and the hives were numbered for the easy identification and tallying of wasp incidence in the apiary.

Table 1. Geographical details of the Indian bee apiaries selected for the study

Sl. No.	Locations (Apiaries)	Latitude	Longitude	Above mean sea level (m)
1.	Balaramapuram (BP 1)	8° 24'00" N	77° 01'46" E	78.50
2.	Nedumangad (NM 1, NM 2, NM 3, NM 4, NM 5)	8° 28'17" N	76° 57'43" E	89.47
3.	Vilappilshala (VS 1, VS 2, VS 3)	8° 31'48" N	77° 02'34" E	69.45
4.	Vellayani (VL 1)	8° 25'45" N	76° 59'16" E	32.16

1a. Apiary at Nedumangad

1b. Apiary at Vilappilshala

Plate 1. Indian bee apiaries

3.1.2 Honey Bee Pests in the Apiaries

The pests associated with Indian bee (Plate 2a) were recorded from the bee hives (Plate 2b) simultaneously while taking observations on wasp incidence. The number of colonies attacked, nature of damage and mode of attack/ predation were also observed.

3.1.2.1 Wax Moth

The wax moths incidence in the apiary was recorded by observing the brood combs of the hive. The different life stages of the pest observed in the hive were also recorded.

3.1.2.2 Spiders

The spiders predating upon the bees near the hives or during the time of foraging around the hives were recorded. The number of honey bees predated by the spiders was also recorded. The spiders were collected in plastic containers and brought to the laboratory and preserved separately in 70 per cent ethyl alcohol (70 parts of 100 per cent alcohol + 30 parts of distilled water). The specimens of the spider were identified with the help of Dr. Sunil K. Jose, Assistant Professor, Department of Zoology, Deva Matha College, Kuravilangad, Kottayam, Kerala, India.

3.1.2.3 Wasp

The incidence and number of wasps seen at a time in the apiaries was recorded. The predatory wasp collected from the apiaries were identified with the help of Dr. K. D. Prathapan, Assistant Professor, Department of Agricultural Entomology, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, India.

3.1.2.4 Ants

The ant species observed in the apiary was identified and the nuisance caused to the bees was recorded.

2a. Indian honey bee, *Apis cerana indica*

2b. Indian bee hive

Plate 2. Beekeeping in hive

3.1.2.5 Lizard

The number of lizards on the hive and their nature of attack on bees was noted.

3.1.2.6 Honey buzzard

The damage caused by the honey buzzard on the hive (brood combs) was recorded.

3.1.2.7 Monkey

The time of raids by the monkeys, number of individuals in a troop and the nature of damage were recorded. The monkeys were identified with the help of Dr. Anoop, R., Teaching Assistant, Department of Animal Husbandry, College of Agriculture, Vellayani.

3.1.3 Seasonal Incidence of Pests of Honey Bees

The occurrence of the honey bee pests during different months of the year was recorded. The peak season of attack by the pests was also determined.

3.2 ESTIMATION OF PREDATORY WASP INCIDENCE

3.2.1 Peak Hour of Wasp Incidence

Observations on wasp incidence in the apiaries were recorded for a period of one year starting from May, 2016 to April, 2017 at weekly intervals (Appendix I). The number of visits done by wasps was tallied.

During the first four weeks, the apiaries facing wasp attack and the peak hour of wasp visits in the field during the day were noted. Four observations (one hour observation^{-1}) in a day was recorded during active foraging hours of honey bees (0930-1030 hr, 1100-1200 hr, 1300-1400 hr and 1430-1530 hr), at weekly intervals for one month. Later, the observations were recorded during that hour of the day with peak wasp incidence.

3.2.2 Incidence of Predatory Wasp

The number of hives attacked by the wasps was noted at each location and the percentage of hives attacked at each apiary was calculated as:

$$\frac{\text{No. of colonies attacked}}{\text{Total no. of colonies}} \times 100$$

The number of visits per hour was also correlated with the hive density. The month and season of the highest wasp incidence was also recorded.

3.2.3 Collection of Meteorological Data

The monthly weather data (temperature, relative humidity and rainfall) from May, 2016 to April, 2017 (Appendix II) collected from the Mithraniketan Krishi Vigyan Kendra (KVK), Thiruvananthapuram was used to conduct correlation studies of mean wasp attacking the colonies (on monthly basis).

3.3 ASSESSMENT OF PREDATORY POTENTIAL OF WASP AND DEFENSIVE STRATEGY OF BEES

3.3.1 Assessment of Predatory Potential of Wasp

The predatory potential of wasp was assessed by observing the number of bees carried away by the wasps at the hive entrances in a day. The observation was taken simultaneously while recording observations on wasp incidence.

3.3.2 Mode of Attack by the Wasp

The predatory strategy adopted by the wasp to prey on the hive bees were carefully observed and recorded visually.

3.3.3 Defense Strategy of Bees

The counter response of hive bees towards the attack of wasps was recorded by placing an injured wasp at the hive entrance. The injury was made by catching a wasp in active flight near the hive using a sweep net and whacking using a wooden plank. The bees' response to the injured wasp was studied. The

natural defense of bees against actively hawking wasps was also recorded by means of photographs and videos.

3.4 FIELD EVALUATION OF BAIT TRAP

The baits were selected by reviewing the previous studies conducted to trap predatory wasps in apiaries. The field efficacy of the baits in attracting the wasp was assessed in four apiaries with maximum wasp incidence.

Design : CRD

Treatments : 5

Replication : 4

Treatments

T_1: Fermented pineapple and molasses (4:1) bait (150 g)

T_2: Beef bait (50g)

T_3: Chicken bait (50g)

T_4: Fish bait (50g)

T_5: Untreated control (water)

3.4.1 Preparation of Baits

The baits were purchased, prepared, weighed and stored separately (to retain the freshness) in refrigerator on the previous day of placement of baits in the field.

3.4.1.1 Fermented Pineapple and Molasses Bait

Fresh pineapple bought from the local market was peeled and the flesh was cut into $1cm^3$ cubes (Plate 3a). Four replications of 120 g was weighed and mixed with the fermenting agent, sugarcane molasses in the ratio 4:1 in the field.

3a. Pineapple + molasses

3b. Beef

3c. Chicken

3d. Fish

Plate 3. Baits used in traps

3.4.1.2 Beef Bait

Fresh beef purchased from the market was cut into 1cm^3 pieces (Plate 3b). Four sets of 50 g was weighed and set in the apiary the next day.

3.4.1.3 Chicken Bait

Fresh chicken bought from the market was cut into 1 cm^3 cubes (Plate 3c) and 50 g per bait was weighed and placed in the apiary in the morning.

3.4.1.4 Fish Bait

Fresh fish (sardine or *matthi*) purchased from the market was cut into pieces (2 cm^3 cubes) (Plate 3d) and four sets of 50 g each was set in the apiary in the morning.

3.4.1.5 Control

Tap water (50 mL) was used as control.

3.4.2 Preparation of Bait Traps

The bait trap was designed by modifying the plastic bottle trap of Bacandristos *et al.* (2006). Two rectangular slits (3 cm x 1 cm) were made in the one litre mineral water bottle horizontally at half the length of the bottle. The baits were placed at the bottom of the bottle and held upright.

3.4.3 Placement of Traps in the Field

During the study, baits were placed in the morning hours (0900 hr) of the day. The bait traps were held in upright position and tied at 2 m height on the rubber tree trunks using a nylon rope (Plate 4). Around the bait traps, insecticidal ant chalks were lined to avoid the ants from entering into the trap and feeding on the baits. The baits were kept thrice in the field and replaced at weekly intervals.

3.4.4 Observations on Wasps and Other Insects Trapped

Observations on the attractiveness of different baits to the predatory wasps were taken one week after the placement of traps by noting the number of wasps

Plate 4. Bait trap established in the apiary

caught in the trap. Its attractiveness to the hive bees and other insects was also recorded by noting the number of honey bees trapped and other pests caught in the traps.

3.5 STATISTICAL ANALYSIS

Analysis of variance of two factors (location and season) without replication was conducted. The wasp incidence was also correlated with the weather parameters (temperature, relative humidity and rainfall) (Panse and Sukhtame, 1954).

Results

4. RESULTS

The study entitled "Seasonal incidence of predatory wasp (*Vespa* spp.) in Indian bee apiaries and evaluation of bait traps" was carried out during 2015-17 in the purposively selected Indian bee apiaries of AICRP (HB and P), Vellayani centre. The results obtained are presented below.

4.1 DOCUMENTATION OF PESTS OF HONEY BEES

4.1.1 Honey Bee Pests in the Apiaries

The pests of honey bees reported from the four locations include wax moth, spiders, predatory wasp, ants, lizard, honey buzzard and monkey (Table 2). The number of colonies attacked, nature of damage and symptoms of attack/ predation caused by the pests are documented below.

4.1.1.1 Wax Moth

The wax moth (*Galleria mellonella* Linnaeus) incidence was observed in all the apiaries. The early instar larvae were seen on the bottom board of the hive while, the grey coloured later instars were seen burrowing and feeding on the wax in the weak colonies (Plate 5a). The pupae were observed in white cocoons on the wooden side bars of brood box and super chamber (Plate 5b). The adult moths, pale yellow to brown in colour were also observed on the hive (Plate 5c). The brood combs were entirely damaged with the black coloured excreta and zig-zag galleries lined with silken web made by the larvae (Plate 5d).

4.1.1.2 Spiders

The spiders predating on the honey bees were identified as giant cross spider *(Argiope anasuja* Thorell*),* two tailed spider (*Hersilia savignyi* Lucas*)* and white crab spider *(Thomisus lobosus* Tikader*).*

Giant cross spider, *A. anasuja*

The spider belonging to the family Araneidae (true orb weavers) was spotted in the apiary at Nedumagad (Plate 6a). The spider positioned itself in a head down position at the centre of the web which was spun on a vertical plane at

Table 2. Honey bee pests recorded from the Indian bee apiaries under study

Sl. No.	Pest category	Common name	Scientific name	Family
1.	Wax moth	Greater wax moth	*Galleria mellonella* Linnaeus	Pyralidae
2.	Spiders	Giant cross spider	*Argiope anasuja* Thorell	Araneidae
		Two tailed spider	*Hersilia savigyni* Lucas	Hersilidae
		White crab spider	*Thomisus lobosus* Tikader	Thomisidae
3.	Wasp	Greater banded hornet	*Vespa tropica* Linnaeus	Vespidae
4.	Ants	Weaver ant	*Oecophylla smaragdina* Fabricius	Formicidae
		Godzilla ant	*Camponotus compressus* Fabricius	
		Yellow crazy ant	*Anoplolepis gracilipes* Smith	
5.	Lizard	Gecko	*Hemidactylus* sp.	Gekkonidae
6.	Honey buzzard	Honey buzzard	*Pernis* sp.	Accipitridae
7.	Monkey	Bonnet macaque	*Macaca radiata* Geoffroy	Cercopithecidae

52

5a. Larva burrowing into brood comb

5b. Pupae of wax moth

5a. Adult wax moth

5d. Infested brood comb with silken web galleries

Plate 5. Infestation of wax moth

6a. *Argiope anasuja*

6b. Bee trapped in spider web

6c. Spider wrapping a bee prey

6d. Bees caught in spider web

Plate 6. Predation of Indian honey bees by giant cross spider

one meter height and 60 cm from the hive entrance (Plate 6b). It had a big brightly coloured abdomen with legs varying in length (Plate 6c). The web also had webbed-up relics of six adult bees on which it predated upon (Plate 6d).

Two tailed spider, *H. savignyi*

Commonly observed on the tree trunks or walls, this species was seen at Balaramapuram apiary on the side bar of the brood chamber about 10 cm above the hive entrance, with the webbed up remains of the bee it devoured on (Plate 7a and 7b). It belongs to the family Hersilidae (tailed spiders) and has big abdomen with long slender legs and spinnerets (Plate 7c). It was dirty white coloured which camouflaged with the hive colour.

White crab spider, *T. lobosus*

They belong to family Thomisidae (crab spiders) and are usually found on flowers and foliage predating on the pollinator bees. The species was spotted camouflaged on the white coloured bee hive at Vellayani. It was firmly holding an adult bee as prey using its crab-like first two pair of legs (Plate 7d). It did not spin webs.

4.1.1.3 Wasp

The wasp predating on the bees was identified as *Vespa tropica* Linnaeus (Plate 8). The head was dark brown or red coloured, while the abdomen was black with a distinct yellow band which covered most of the second abdominal segment. It actively predated on the forager bees in and around the hive. One to four wasps were seen at a time near the hives in the brood rearing season.

4.1.1.4 Ants

Ants were observed moving near the hive entrances and on the hive stand. They feed on honey and seize on weak and lonely worker bees and larvae and carry them to their nests individually or in groups of 2-10. The ants observed were weaver ant or green ant, *Oecophylla smaragdina* Fabricius (Plate 9a),

7a. Spider wrapping a bee

7b. Bee wrapped in spider web

7c. *Hersilia savigyni*

7d. *Thomisus lobosus* capturing a bee

Plate 7. Predation of Indian bees by two tailed spider and white crab spider

Plate 8. Greater banded hornet, *Vespa tropica*

9a. *Oecophylla smaragdina*

9b. *Camponotus compressus*

9c. *Anoplolepis gracilipes*

Plate 9. Ant pests in the apiary

common godzilla ant, *Camponotus compressus* Fabricius (Plate 9b) and yellow crazy ant, *Anoplolepis gracilipes* Smith (Plate 9c).

4.1.1.5 Lizard

Lizards (*Hemidactylus* sp.) were seen, one per hive at a time, loitering around and hiding under the shades of the hive waiting to prey on weak bees (Plate 10). On sighting a weak bee, they come out of their hiding place to catch it with their mouth and feed on it by quickly returning to the shelter.

4.1.1.6 Honey Buzzard

Honey buzzards were observed during the morning hours of the day. They approached the hives and loosen the tightly tied rope around the hive with their beaks and claws. The top cover was broke open and the entire hive was shattered and the brood was found to be taken away by the birds (Plate 11). They protected themselves from the bees by blowing up their plumes.

4.1.1.7 Monkey

The monkey at the apiary was identified as bonnet macaque (*Macaca radiata* Geoffroy). The starving monkeys (Plate 12a) raided the apiaries in troops of three during the morning hours of the day and shattered the hives in search of food. They managed to open up the hives and fed on the brood and honey combs as such (Plate 12b).

4.1.2 Incidence of Pests of Honey Bees

The incidence of the pests of honey bees in the apiaries selected at various locations during the period of study is illustrated in Table 3.

Though pests were observed throughout the year, the frequency of occurrence of pests showed wide fluctuations during different seasons. Among the three beekeeping seasons, the pest attack was the highest during brood rearing season. The wax moths were present almost throughout the year except in June and July whereas, the spiders were observed in and around the hives from August-December and March-April. Ants were observed moving on and near the hives

Table 3. Seasonal incidence of honey bee pests in the Indian bee apiaries under study (May, 2016-April, 2017)

Beekeeping season	Month	Wax moth	Spider	Wasp	Ants	Lizard	Honey buzzard	Monkey
Lean season	May	+	-	-	+	-	-	-
	Jun.	-	-	-	+	-	-	-
	Jul.	-	-	-	+	-	-	-
	Aug.	+	+	+	+	-	-	-
Brood rearing season	Sep.	+	+	+	+	+	-	-
	Oct.	+	+	+	+	+	+	-
	Nov.	+	+	+	+	-	+	-
	Dec.	+	+	+	+	-	-	-
Honey flow season	Jan.	+	-	-	+	-	-	-
	Feb.	+	-	-	+	-	-	-
	Mar.	+	+	-	+	+	-	+
	Apr.	+	+	+	+	+	-	+

Plate 10. Lizard in the apiary

Plate 11. A hive shattered by honey buzzard

12a. Monkey arriving at the apiary

12b. Monkey feeding on brood comb

Plate 12. Monkeys in the apiaries

throughout the year. Lizards were observed during September-October and March-April. Honey buzzard and monkeys were occasionally seen in the apiaries. Honey buzzard were witnessed during October-November while, the monkeys raided the apiaries during the dry months of March and April.

The percentage of colonies attacked by the pests is provided in Table 4. The incidence of ants were noted in 100 per cent colonies, followed by wasps (59.86 %), wax moths (34.87 %), spiders (2.63 %) and lizard (1.97 %), whereas the incidence of honey buzzard and monkeys was 1.32 % each.

4.2 ESTIMATION OF PREDATORY WASP INCIDENCE

The seasonal incidence of predatory wasp was assessed by noting the total number of bee hives attacked, peak period of wasp incidence during the day and the total wasp incidence during the beekeeping seasons.

4.2.1 Peak Hour of Wasp Incidence

The observations on the wasp visits during different hours of the day (for four weeks *viz.,* week 35- week 38) revealed 0930-1030 hr. as the peak hour of attack (Table 5). Out of 62 wasp incidences, maximum visits hour^{-1} (26 Nos.) were recorded at 0930- 1030 hr and the minimum visits hr^{-1} (8 Nos.) at 1300-1400 hr. The number of wasp visits apiary^{-1} ranged from 3 to 28, with the maximum at NM 2 of Nedumangad and minimum at VL 1 of Vellayani.

4.2.2 Incidence of Predatory Wasp

Out of the 152 hives present, the wasps pounced on the bees in 91 hives, climaxing the per cent of colonies attacked to 59.86 per cent (Table 6). The wasp attack ranged from 0 to 100 per cent, with 100 per cent attack in the three apiaries (NM 2 and NM 4 at Nedumangad and VS 2 at Vilappilshala). No wasp visits were observed in the apiary NM 5 of Nedumangad. Among the colonies attacked, NM 3 of Nedumangad reported the least incidence with 20 per cent attack.

A significant positive correlation (0.633) was recorded with the wasp incidence and the number of hives in the apiary (Table 7).

Table 4. Percentage incidence of pests in the Indian bee apiaries

Sl. No.	Pest	No. of colonies attacked	Incidence (%)
1.	Wax moth	53	34.87
2.	Spiders	4	2.63
3.	Wasps	91	59.86
4.	Ants	152	100.00
5.	Lizard	3	1.97
6.	Honey buzzard	2	1.32
7.	Monkey	2	1.32

Table 5. Wasp incidence in the Indian bee apiaries at different hours of the day

Time (hour)	No. of visits apiary^{-1} hour^{-1}				
	NM 2	VS 1	VS 2	VL 1	Total
0930-1030	12	8	5	1	26
1100-1200	5	3	3	1	12
1300-1400	3	2	3	0	8
1430-1530	8	3	4	1	16
	28	16	15	3	62

NM- Nedumangad VS- Vilappilshala VL- Vellayani

Table 6. Percentage infestation by the wasp in the Indian bee apiaries

Sl. No.	Location	Apiary	No. of hives	No. of hives attacked	Percentage
1.	Nedumangad	NM 1	15	4	26.67
2.		NM 2	20	20	100.00
3.		NM 3	20	4	20.00
4.		NM 4	11	11	100.00
5.		NM 5	10	0	0.00
6.	Vilapilshala	VS 1	20	13	65.00
7.		VS 2	20	20	100.00
8.		VS 3	13	8	61.54
9.	Vellayani	VL 1	10	8	80.00
10.	Balaramapuram	BP 1	13	3	23.08
	Total		152	91	Average-59.86

NM- Nedumangad VS- Vilappilshala VL- Vellayani BP-Balaramapuram

Table 7. Influence of wasp incidence to the Indian bee hives

	No. of hives	Wasp incidence
No. of hives	1	
Wasp incidence	0.633*	1

*Significant at 5 % level

Out of the 489 wasp incidences, the maximum (212 visits) was reported from NM 2, Nedumangad, while the minimum (0 visits) was from NM 5, Nedumangad (Table 8).

The wasp incidences started from 35th standard week and continued up to 50th week (August to December). From a total of 52 standard weeks in the year, the wasp visits in the field occurred only for 15 weeks. Sporadic incidence (2 visits hour^{-1}) was seen during 16th week (April) at NM 3, Nedumangad. The peak population of wasp (110 visits week^{-1}) was observed at 44th week (November).

The wasp incidences was the highest in November with a mean of 6.03 visits per month, followed by October, December, September and August with 5.10, 2.26, 1.67 and 0.90 visits, respectively. Sporadic incidence was seen in April (0.07 visits) at Nedumangad (Table 9).

The wasp occurrence started in the lean season (May to August) and was the highest in the brood rearing season (September to December). Rare occurrence was seen in honey flow season (Table 10).

The statistical analysis indicated that the brood rearing season was significantly different from the other two seasons (lean season and honey flow season) which were non-significant (on par) at 0.05 per cent level (Table 11).

4.2.3 Correlation with Meteorological Data

The correlation of monthly wasp incidence with the weather data showed a non-significant relationship with all the weather parameters. Relative humidity had a positive correlation whereas, temperature and rainfall showed a negative correlation (Table 12).

Table 8. Incidence of predatory wasps in the Indian bee apiaries at weekly intervals

Standard week		No. of visits apiary^{-1} week^{-1}										
		NM 1	NM 2	NM 3	NM 4	NM 5	VS 1	VS 2	VS 3	VL 1	BP 1	Total
May	Week 18	0	0	0	0	0	0	0	0	0	0	0
	Week 19	0	0	0	0	0	0	0	0	0	0	0
	Week 20	0	0	0	0	0	0	0	0	0	0	0
	Week 21	0	0	0	0	0	0	0	0	0	0	0
Jun.	Week 22	0	0	0	0	0	0	0	0	0	0	0
	Week 23	0	0	0	0	0	0	0	0	0	0	0
	Week 24	0	0	0	0	0	0	0	0	0	0	0
	Week 25	0	0	0	0	0	0	0	0	0	0	0
	Week 26	0	0	0	0	0	0	0	0	0	0	0
Jul.	Week 27	0	0	0	0	0	0	0	0	0	0	0
	Week 28	0	0	0	0	0	0	0	0	0	0	0
	Week 29	0	0	0	0	0	0	0	0	0	0	0
	Week 30	0	0	0	0	0	0	0	0	0	0	0
Aug.	Week 31	0	0	0	0	0	0	0	0	0	0	0
	Week 32	0	0	0	0	0	0	0	0	0	0	0
	Week 33	0	0	0	0	0	0	0	0	0	0	0
	Week 34	0	0	0	0	0	0	0	0	0	0	0
	Week 35	0	7	0	3	0	9	9	0	2	1	31
Sep.	Week 36	0	4	0	2	0	5	0	0	0	0	11
	Week 37	0	0	0	0	0	0	0	0	0	0	0
	Week 38	1	16	0	1	0	2	0	0	0	0	20
	Week 39	0	10	1	5	0	1	0	0	0	0	17
Oct.	Week 40	0	2	0	5	0	0	13	8	0	0	28
	Week 41	0	0	0	0	0	7	0	0	0	0	7
	Week 42	0	21	0	0	0	28	0	0	0	0	49
	Week 43	0	37	5	0	0	0	22	0	9	0	73
Nov.	Week 44	0	65	3	0	0	4	25	0	13	0	110
	Week 45	3	12	1	0	0	9	1	0	10	0	36
	Week 46	0	0	0	0	0	0	0	0	0	0	0
	Week 47	0	9	0	2	0	5	4	0	1	0	21
Dec.	Week 48	5	6	0	0	0	6	16	0	0	3	36
	Week 49	0	15	0	0	0	0	12	0	0	0	27
	Week 50	0	8	0	0	0	0	13	0	0	0	21
	Week 51	0	0	0	0	0	0	0	0	0	0	0
	Week 52	0	0	0	0	0	0	0	0	0	0	0
Jan.	Week 1	0	0	0	0	0	0	0	0	0	0	0
	Week 2	0	0	0	0	0	0	0	0	0	0	0
	Week 3	0	0	0	0	0	0	0	0	0	0	0

	Week 4	0	0	0	0	0	0	0	0	0	0	0
Feb.	Week 5	0	0	0	0	0	0	0	0	0	0	0
	Week 6	0	0	0	0	0	0	0	0	0	0	0
	Week 7	0	0	0	0	0	0	0	0	0	0	0
	Week 8	0	0	0	0	0	0	0	0	0	0	0
Mar.	Week 9	0	0	0	0	0	0	0	0	0	0	0
	Week 10	0	0	0	0	0	0	0	0	0	0	0
	Week 11	0	0	0	0	0	0	0	0	0	0	0
	Week 12	0	0	0	0	0	0	0	0	0	0	0
	Week 13	0	0	0	0	0	0	0	0	0	0	0
Apr.	Week 14	0	0	0	0	0	0	0	0	0	0	0
	Week 15	0	0	0	0	0	0	0	0	0	0	0
	Week 16	0	0	2	0	0	0	0	0	0	0	2
	Week 17	0	0	0	0	0	0	0	0	0	0	0
Total		9	212	10	18	0	76	115	8	35	4	489

NM- Nedumangad VS- Vilappilshala VL- Vellayani BP-Balaramapuram

Table 9. Monthly incidence of predatory wasps in the Indian bee apiaries

Apiary	Visits apiary^{-1} month^{-1}										Total	Mean
	NM 1	NM 2	NM 3	NM 4	NM 5	VS 1	VS 2	VS 3	VL 1	BP 1		
May-16	0	0	0	0	0	0	0	0	0	0	0	0
Jun-16	0	0	0	0	0	0	0	0	0	0	0	0
Jul-16	0	0	0	0	0	0	0	0	0	0	0	0
Aug-16	0	7	0	3	0	9	9	0	0	0	28	0.90
Sep-16	1	30	1	8	0	7	0	0	2	1	50	1.67
Oct-16	0	60	5	5	0	36	35	8	9	0	158	5.10
Nov-16	8	92	4	2	0	18	30	0	24	3	181	6.03
Dec-16	0	23	0	0	0	6	41	0	0	0	70	2.26
Jan-17	0	0	0	0	0	0	0	0	0	0	0	0
Feb-17	0	0	0	0	0	0	0	0	0	0	0	0
Mar-17	0	0	0	0	0	0	0	0	0	0	0	0
Apr-17	0	0	2	0	0	0	0	0	0	0	2	0.07
Total	9	212	12	18	0	76	115	8	35	4	489	

NM- Nedumangad VS- Vilappilshala VL- Vellayani BP-Balaramapuram

Table 10. Seasonal incidence of predatory wasp in Indian bee apiaries

Apiary	Visits apiary^{-1} season^{-1}		
	Lean season	Brood rearing season	Honey flow season
NM1	0	9	0
NM2	7	205	0
NM3	0	10	2
NM4	3	15	0
NM5	0	0	0
VS1	9	67	0
VS2	9	106	0
VS3	0	8	0
VL1	0	35	0
BP1	0	4	0
Total	28	459	2

NM- Nedumangad VS- Vilappilshala VL- Vellayani BP-Balaramapuram

Table 11. Location wise incidence of predatory wasps in the Indian bee apiaries during different seasons

Apiary location	Visits location^{-1} season^{-1}		
	Lean season	Brood rearing season	Honey flow season
Nedumangad	10 (3.32)	239 (15.49)	2 (1.73)
Vilappilshala	18 (4.36)	181 (13.49)	0 (1.00)
Vellayani	0 (1.00)	35 (6.00)	0 (1.00)
Balamapuram	0 (1.00)	4 (2.24)	0 (1.00)
CD (0.05)	NS	5.53	NS

(The values in parenthesis represent square root ($\sqrt{}$ (x + 1)) transformed values)
NS: Not significant at 5 % level

Table 12. Influence of weather parameters to wasp incidence

Weather parameters	Correlation coefficient
Maximum temperature	-0.283*
Relative humidity	0.183*
Rainfall	-0.227*

*Non-significant at 5% level

4.3 ASSESSMENT OF PREDATORY POTENTIAL OF WASP AND DEFENSIVE STRATEGY OF BEES

4.3.1 Assessment of Predatory Potential of Wasps

The predatory wasps carried a total of 52 bees from the apiaries (NM 2 of Nedumangad, VS 1 and VS 2 of Vilappilshala and VL 1 of Vellayani) during the entire period of study. Despite of the wasps' active presence in the apiaries for fifteen weeks, the predation was observed only for five weeks (41st to 44th week and 48th week) which also coincided with the months of October, November and December. The maximum number of bees (18 Nos.) was predated at the 44th week at Nedumangad. Highest predation on bee was recorded from Nedumangad (29 Nos.), followed by Vilappilshala (21 Nos.) and Vellayani (2 Nos.) (Table 13).

4.3.2 Mode of Attack by the Wasp

The mode of attack of wasps was studied by observing the arrival, approach, attack and predation of the wasps on the bees

The arrival of the wasp was marked by visual observation from a distance of 4-5 m along with the buzzing sound of its flight, which increased as it moved inside the apiary. The wasp moved from one extreme of the apiary to the other along the row of hives in a straight path and returned back the same way. After two to three rounds to and fro trip, the colony to be attacked was selected.

The wasp approached the hive with a pause and hovered over the hive, occasionally trying to land on it. It mostly hovered near the hive entrance but, cracks and crevices on the hive and the space between the hive components were also looked into as a point of entry (Plate 13a). The wasp then halted on the surface of the hive or near the entrance or alighting board and crept around targeting single bees.

After halting on the hive surface, the wasp moved about and peeped into the hives through the crevices. On sighting the bees inside the hives, it inserted its powerful mandibles through the crevices to catch and crush the prey. On repeated

Table 13. Predation of Indian bees by the wasp

Standard week	No. of bees predated by wasp apiary^{-1} week^{-1}				Total
	NM 2	VS 1	VS 2	VL 1	
Week 41	0	3	0	0	3
Week 42	0	5	0	0	5
Week 43	11	0	0	2	13
Week 44	18	0	0	0	18
Week 48	0	0	13	0	13
Total	29	8	13	2	52

NM- Nedumangad VS- Vilappilshala VL- Vellayani BP-Balaramapuram

13a. Wasp searching for a point of entry into the chamber

13b. Wasp approaching foraging bees

13c. A bee-hunting wasp inside the hive

Plate 13. Predatory strategies of wasps

failure to catch the prey, the wasp slowly recoiled and moved on to another hive. Four wasps at a time were observed attacking a single colony.

The wasp predation was successful when it pounced on the bees immediately after halting near the entrance (Plate 13b). The wasps used its legs and mandibles to grasp on the bee. Immediately after the catch, the wasps showed a jerky movement downwards, almost half way down the hive and then soared up in a straight flight onto the branches of the rubber tree. The bees were mauled and killed using mandibles. Predatory wasps were also observed inside the hive of absconded colonies (Plate 13c).

4.3.3 Defense Strategy of Bees

The response of bees on placing an injured wasp at the hive entrance as well as on top of the hive was learnt to be nil as they continued to forage as usual. Though it failed to draw the attention of the bees, another wasp attended the injured wasp and nursed it. The injured wasp later succumbed to the injuries.

It was observed that, the wasp entered into the hive and spent ample time to prey on weak colonies. It moved outside the hive only on tapping the hive on top. On lifting up of the top cover of the hive, the wasp was found in the super chamber, attempting to prey on the bees in the brood box.

The persistent attack by the wasp was seen to provoke the bees to exhibit characteristic defense behaviour. The bees ceased their foraging activities and were involved in colony defense. A few bees flew around the threat with strong buzzing sound whereas, the others were found to guard the entrance by clustering and waiting for an opportunity to counter-attack the wasp. A failed attempt to prey on the bee resulted in some hundreds of frustrated bees engulf the wasp tightly, almost rendering it immovable (Plate 14). The wasp was almost invisible in the ball and struggled to escape. After a struggle for about ten minutes, the wasp however, managed to escape as the colony was weak with only some thousands of bees in it.

Plate 14. Balling behaviour of Indian honey bees

4.4 FIELD EVALUATION OF BAIT TRAP

4.4.1 Response of Wasps to Bait Traps

The wasps' response to the traps immediately after its placement was nil as they were not attracted to the baits on the day of its placement. They were found trapped, drowned and lifeless in the pineapple molasses trap one week after its placement. The response to all other traps was nil. The wasps visit to the apiaries continued even after the placement of baits (9.92 visits $hour^{-1}$) (Table 14).

4.4.2 Observations on Wasps and Other Insects Trapped in Different Bait Traps

The fermented pineapple + molasses trap trapped wasps (0.5 Nos. $trap^{-1}$) at Nedumangad one week after the placement of traps (Plate 15a and 15b). The wasps were found drowned in the sticky molasses. The positive result of the trap was masked, as the trap also caught adult bees (Table 14) (17.42 Nos. $trap^{-1}$) (Plate 15c).

The beef bait attracted the Dipteran flies which laid eggs and bred maggots which fed on it. The bait gradually dried up.

The chicken bait attracted the weaver ants which almost filled the trap within minutes of bait placement.

The fish bait attracted the least insects which mainly included the muscoid flies. No insects were trapped in the control.

Proportionally, pineapple + molasses trap comprised of a higher catch of non-target species compared to other traps. Among the different insects caught, fruit moths (Plate 16a) and butterfly (Lepidoptera), flower beetle (Plate 16b), red palm weevil (Plate 16c) and longicorn beetle (Plate 16d) (Coleoptera) and other muscoid flies (Diptera) were observed.

Table 14. Efficacy of bait traps against predatory wasp in the Indian bee apiaries

Baits	No. of wasps attracted	No. of bees attracted	No. of wasps visited at hive entrances*
Fermented pineapple + molasses	0.5	17.42	9.92
Beef	0	0	
Chicken	0	0	
Fish	0	0	
Control	0	0	

*Total hives subjected to treatments

15a. Wasps trapped in fermented pineapple molasses trap

15b. Wasps killed in the trap

15c. Bees trapped along with wasps

Plate 15. Wasps and bees caught in bait trap

16a. Fruit moth

16b. Flower beetle

16c. Red palm weevil

16d. Longicorn beetle

Plate 16. Other insects trapped

Discussion

5. DISCUSSION

The present study was conducted at Department of Agricultural Entomology, College of Agriculture, Vellayani during 2015-17 to study the seasonal incidence of *Vespa* spp. in Indian honey bee apiaries, assessment of its predatory potential and evaluation of bait traps against the wasp. The results obtained are discussed below:

5.1 DOCUMENTATION OF PESTS OF HONEY BEES

Analysis of honey bee pests from four locations *viz.*, Nedumangad, Vilappilshala, Vellayani and Balaramapuram revealed that the bees were attacked by wax moth, spiders, wasps, ants, lizard, honey buzzard and monkey.

The greater wax moth, *Galleria mellonella* observed in the apiaries has already been reported as pests from various parts of the world. In the present study, the wax moth occurred throughout the year except in June and July and 34.87 per cent of colonies were found infested. In Sudan, 64.50 per cent beekeepers revealed wax moth as pest with 86.30 per cent of the colonies infested (El-Niweiri and Satti, 2008), while in India, greater wax moth has been reported as pest of honey bees in Punjab (Brar *et al.*, 1985; Brar *et al.*, 1992a; Brar *et al.*, 1996; Deosi *et al.*, 2014), Jammu and Kashmir (Abrol and Kakroo, 1996), Uttarakhand (Varshneya *et al.*, 2008), Odisha (Mishra *et al.*, 2009a; Satapathy and Mohapatra, 2015), Assam (Deka *et al.*, 2010), Uttar Pradesh (Vishwakarma *et al.*, 2012) and Kerala (KAU, 2016). The observations on larval and pupal stages of wax moth and the damage caused were similar to those reported by Williams (1978).

During the course of investigation, giant cross spider *(A. anasuja),* two tailed spider (*H. savignyi)* and white crab spider *(T. lobosus)* were seen predating on the honey bees near the hives. Though *H. savigyni* and *T. lobosus* has already been reported as predators of stingless bee by Jayalekshmi (2015), no reports on predation on Indian bee has been found. The spider species reported as predators varied with the locations. The predation of the honey bees (*Apis* spp.) by the

spiders, *Nephila kuhlii* from Nepal (Pokhrel *et al.,* 2006), Salticids and Thomisids from Sudan (El- Niweiri and Satti, 2008), and *Sparssus* sp. and *Paradosa* sp. from Himachal Pradesh (Sharma *et al.*, 2013) has already been reported. In the present study, the spiders were observed in and around the hives from August-December and March-April, while in Nepal its incidence was reported throughout the year (Pokhrel *et al.*, 2006). Such disparity may be due to difference in climate and the diversity of native spiders present in that area. While in the current study, damage was estimated in terms of colonies infested (2.63 %), Kinati *et al.* (2012) assessed the damage by interviewing beekeepers of Ethiopia and reported 1.90 per cent infestation of spiders in their apiaries.

The predatory attacks of the wasp, *Vespa tropica* on forager bees in and around the hives has been reported by various workers (Burget and Akratanakul, 1982; Gulati and Kaushik, 2004; Ranabhat and Tamrakar, 2008; Swamy, 2008; Varshneya *et al.*, 2009; Munawar and Camphor, 2009; Bhatta and Tamrakar, 2011; Sharma *et al.*, 2013; Sharma and Mattu, 2014; Islam *et al.*, 2015). Though the wasp attack is mainly observed during August to December months in Kerala (AICRP, 2013), Subbiah and Mahadevan (1957) reported its attack during the periods of low breeding activity (June-December) at Coimbatore, thus leading to weakening and perishing of the colony. In Solan, the wasps were observed in the apiary during September and a maximum of seven wasps day^{-1} was recorded in October (Kumar *et al.*, 1998) while in Nepal, the wasps (*Vespa cincta* and *V. orientalis*) were most damaging during the rainy season (Pokhrel *et al.*, 2006). The wasps hawked 59.86 per cent of the hives in the present study. However, in the hilly lands of Ethiopia, the incidence has been recorded by enquiring the beekeepers, among which 1.70 per cent reported it as a nuisance in the apiaries (Kinati *et al.*, 2012).

In the present investigation, weaver ant (*Oecophylla smaragdina*), common godzilla ant (*Camponotus compressus*) and yellow crazy ant (*Anoplolepis gracilipes*) were observed as pests. While examining the bee hives for the presence of pests, Swamy (2008) found *O. smaragdina* and *Camponotus*

sp. as predator of honey bees in Karnataka while *O. smaragdina* alone was reported from European bee hives by Vishwakarma *et al.* (2012). This is in accordance with the findings of the present study but yellow crazy ant was not reported as pests in any of the studies. These ants were observed moving on and near the hives throughout the year and caused cent per cent infestation on the hives. The damage due to ants was reported to be 95.70 per cent in the bee colonies of Sudan (El-Niweiri and Satti, 2008). Literature on ants as pest of honey bees and the estimate of damage incurred are meagre.

Lizard (*Hemidactylus* sp.) was seen loitering around and hiding under the shades of the hive waiting to predate on weak bees. Small geckos belonging to the same genus (*H. flaviviridis*) has been reported from Nepal (Pokhrel *et al.*, 2006) and Nigeria (*H. fasciatus* and *H. brooki*) as frequent visitors in bee colonies (Lawal and Banjo, 2007). Reports of lizard pests from India are scarce and are often unidentified. In the current investigation, they were observed during September-October and March-April in 1.97 per cent colonies. But, in Ethiopia, only 0.80 per cent of the beekeepers reported it as a pest (Kinati *et al.*, 2012). Reports on damage due to lizards are scanty.

Honey buzzards and monkeys were occasionally seen in the apiaries. The oriental honey buzzard (*Pernis* sp.) has been stated as specialist's predators of honey bees by Oldroyd and Nanork (2009). In the study on the status and distribution of raptors in Wayanad of Kerala, Kurup (2011) noticed *P. ptilorhynchus* invading the wild bee colonies while, Basavarajappa and Raghunandan (2013) has reported its incidence from rock bee colonies in Karnataka. Despite of the name honey buzzard, its main diet apart from bees consists of social wasps too (Birkhead, 1974). In the present study, the honey buzzards were observed during the months of October and November while, in Wayanad it was observed during the honey flow season (March- May). The spotting of the birds during the same months of wasp occurrence and its preference of wasps as prey than bees, suggest that the incidence of wasp might have triggered the attack. The visits by monkeys during the dry months of March

and April may be attributed to the famine conditions and starvation during the period. Moreover, these pests were observed only in the apiaries near to forests and hilly areas. The least number of hives were damaged by honey buzzards and monkeys (1.32 % each). No reports on the loss due to honey buzzards and monkeys were found. The monkeys raided the apiaries in troops and shattered the hives to feed on the brood and honey combs. But unlike the observations of Krishnamurthy (1990), they were not found to smear mud on themselves to protect themselves from bee stings. Sohela (2013) reported monkeys as pests in the beekeeping areas of the Sundarbans.

From the documentation of pests, it is evident that nature of damage and incidence of bee pests varied based on the geographical and ecological conditions. In the present study, though pests were observed throughout the year, the frequency of occurrence of pests showed wide fluctuations during different seasons. Among, the different seasons of beekeeping, the highest pest incidence was during the brood rearing season.

5.2 ESTIMATION OF PREDATORY WASP INCIDENCE

Studies on the wasp visits in the apiary during different hours of the day revealed 0930 - 1030 hr (morning hours) as the peak hour of attack. The peak foraging activity of bees during these hours might be the reason for this. The results confirmed the reports of Vishwakarma *et al.* (2012), who also reported morning hours as active hours of wasp occurrence while, it contradicted the observations of Brar *et al.* (1985), Abd Al- Fattah *et al.* (2014) and Varshneya *et al.* (2009) who reported noon hours of the day (1200-1400 hr, 1300-1600 hr and 1200-1600 hr, respectively) as peak hours. However, Ranabhat and Tamrakar (2008), observed both morning (0700-0900 hr) and afternoon (1200-1400 hr) hours as peak time of attack. Similarly, Islam *et al.* (2015) also recorded 0800-1100 hr and 1500-1800 hr as the peak foraging hours of wasp in the European bee apiaries of Pakistan.

In contrast to 59.86 per cent of colonies attacked by wasps in the present study, in Sudan the loss was reported to be 22.60 per cent (El-Niweiri and Satti, 2008). However, in Indian bee apiaries of Karnataka, the loss reported was not only due to predation but also, due to absconding (67.50 per cent colonies) (Pradeepa and Bhat, 2014).

Correlation studies of the wasp incidence with the number of hives in the apiary recorded a significant positive result which was in agreement with the hypothesis of Chhuneja (2014) who stated that the density of hives in apiary played a role in attracting predatory wasps.

The wasp incidences started from 35th standard week and continued up to 50th week (August to December). From a total of 52 standard weeks in the year, the wasp visits in the apiaries occurred only for 15 weeks. Sporadic incidence (2 visits hr^{-1}) was seen during 16th week (April). While in the present study, the peak population of wasp (110 visits week^{-1}) was observed at 44th week (November), Varshneya *et al.* (2009) stated 37th to 39th standard week (September) as the peak period.

The *Vespa tropica* incidences was highest in November (181 Nos.) followed by October, December, September and August with 158, 70, 50 and 28 wasp visits hour^{-1}, respectively (Fig. 1). In Punjab, Chhuneja (2014) observed the peak hornet (*V. orientalis*) population in September, October and August months. Studies in Egypt revealed the peak incidence of wasp (*V. orientalis*) in October (9.60 hornets colony^{-1} 3 minute^{-1}) (Abd Al-Fattah *et al.*, 2014). Islam *et al.* (2015) also reported October as the peak month of wasp occurrence in Pakistan. Sporadic incidence was seen in April. Thus dissimilarity in the peak wasp incidence was observed in the different studies conducted throughout the country. This may be due to the variation in *Vespa* species present and also due to the climatic and geographic variation. Also, the duration adopted by different researchers to find the peak wasp incidence is different.

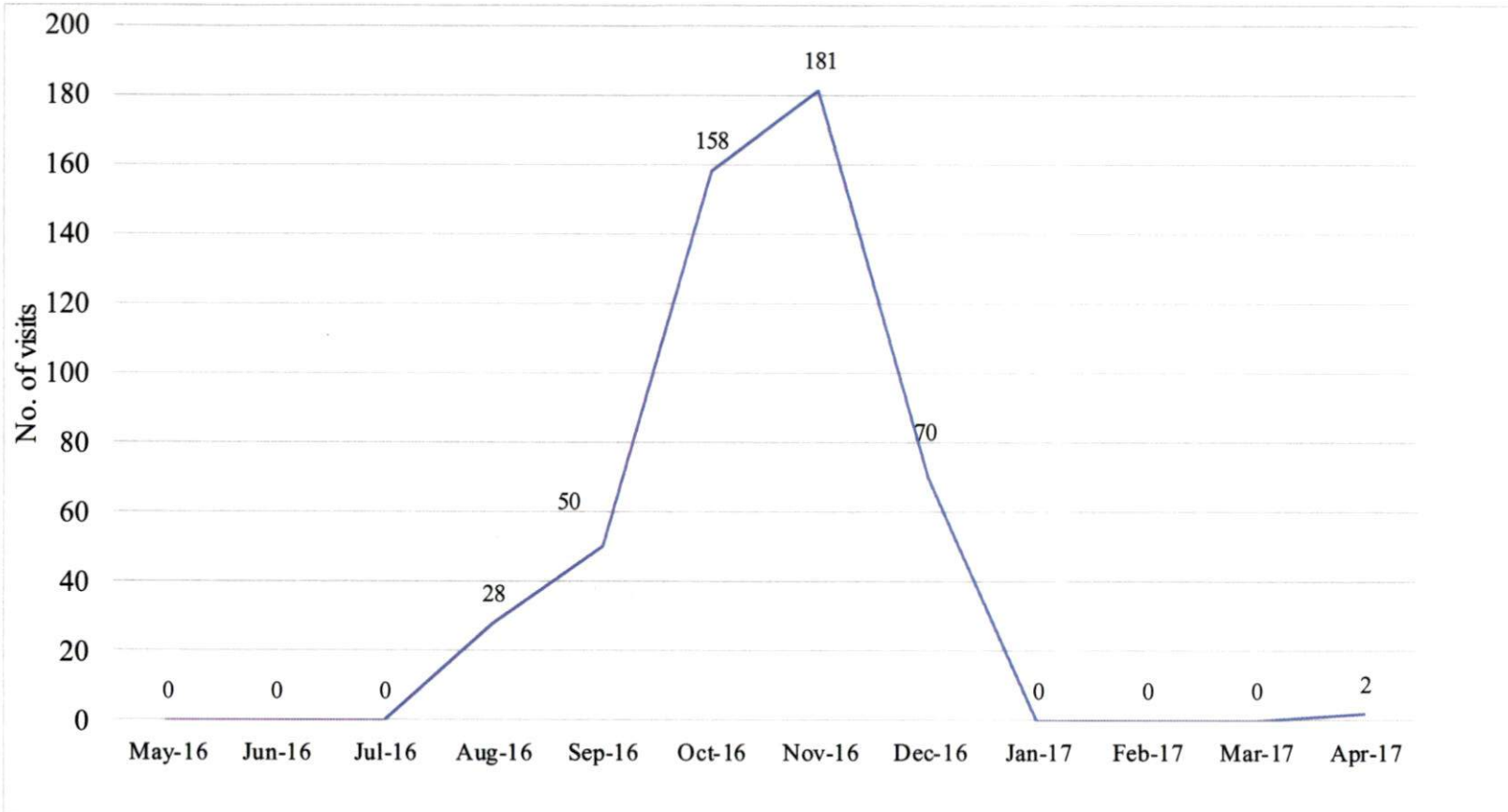

Figure 1. Month wise incidence of predatory wasp in the Indian bee apiaries

Though the wasp occurrence started during the lean season (May to August), maximum incidence was observed in the brood rearing season (September to December) (Fig. 2). This might be because the wasps also nurture their young ones (with protein rich adult honey bee) during these months. Also, the volatiles from the pollen and honey stored for the brood nutrition might be easily detected by wasp with their strong sense of olfaction (Couto *et al.*, 2014). Rare occurrence of the wasp was recorded during the honey flow season. Honey bees which are a good source of protein (pollen) and carbohydrate (honey) serves as the best source of nutrition for wasps. The biology of wasps also showed that the worker wasp population emerge during this period (mid-July) followed by the male wasps in mid-September (Bequaret, 2016). The results are in congruence with those of Subbiah and Mahadevan (1957), Swamy (2008), Ranabhat and Tamrakar (2008), Varshneya *et al.* (2009), Vishwakarma *et al.* (2012), Chhuneja (2014), Abd Al-Fattah *et al.* (2014) and Islam *et al.* (2015).

The correlation of monthly wasp incidence with the weather data showed a non-significant relationship with all the weather parameters (Fig. 3). Relative humidity had a positive correlation whereas, temperature and rainfall showed a negative association. These results totally contradicted other such studies. However, this may be because of the changes in the climatic conditions prevailing in the region of study. According to Abdel-Gahnny *et al.* (2008), in Egypt, the wasps (*Vespa orientalis*) frequently visited the apiaries from April-November when the temperature range was 23-38 °C. In an experiment in Punjab, Chunneja *et al.* (2008) observed a positive correlation between the mean daily total wasp populations and mean maximum and minimum temperatures, mean daily temperature and mean relative humidity. Later, his study was confirmed by Varshneya *et al.* (2009), Sharma and Mattu (2014) and Chhuneja (2014) who also concluded that temperature and relative humidity had a positive association with wasp population. Contrarily, Islam *et al.* (2015) found that the wasp population had a negative correlation with temperature and positive correlation with relative humidity.

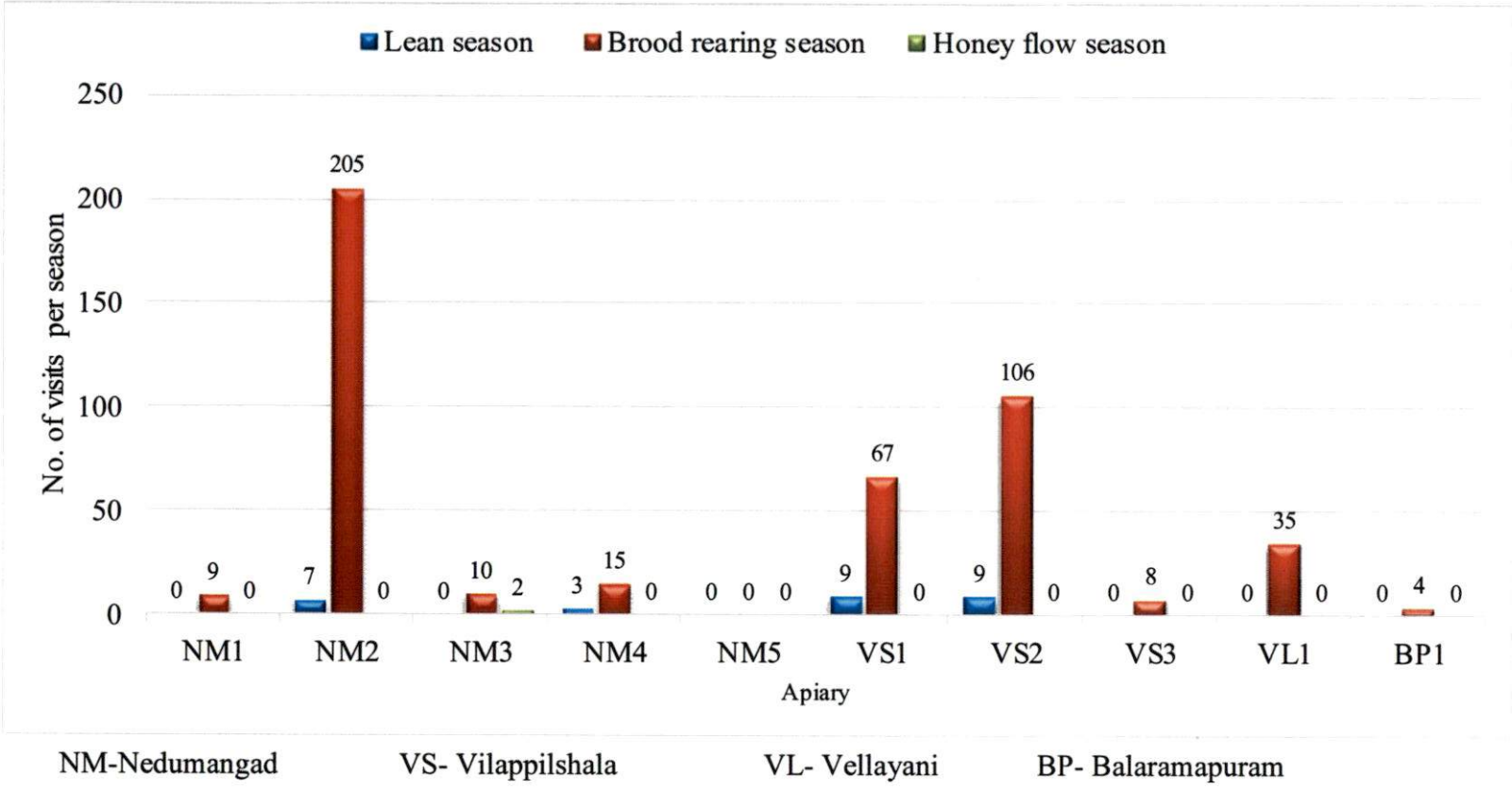

Figure 2. Seasonal incidence of predatory wasp in the Indian bee apiaries

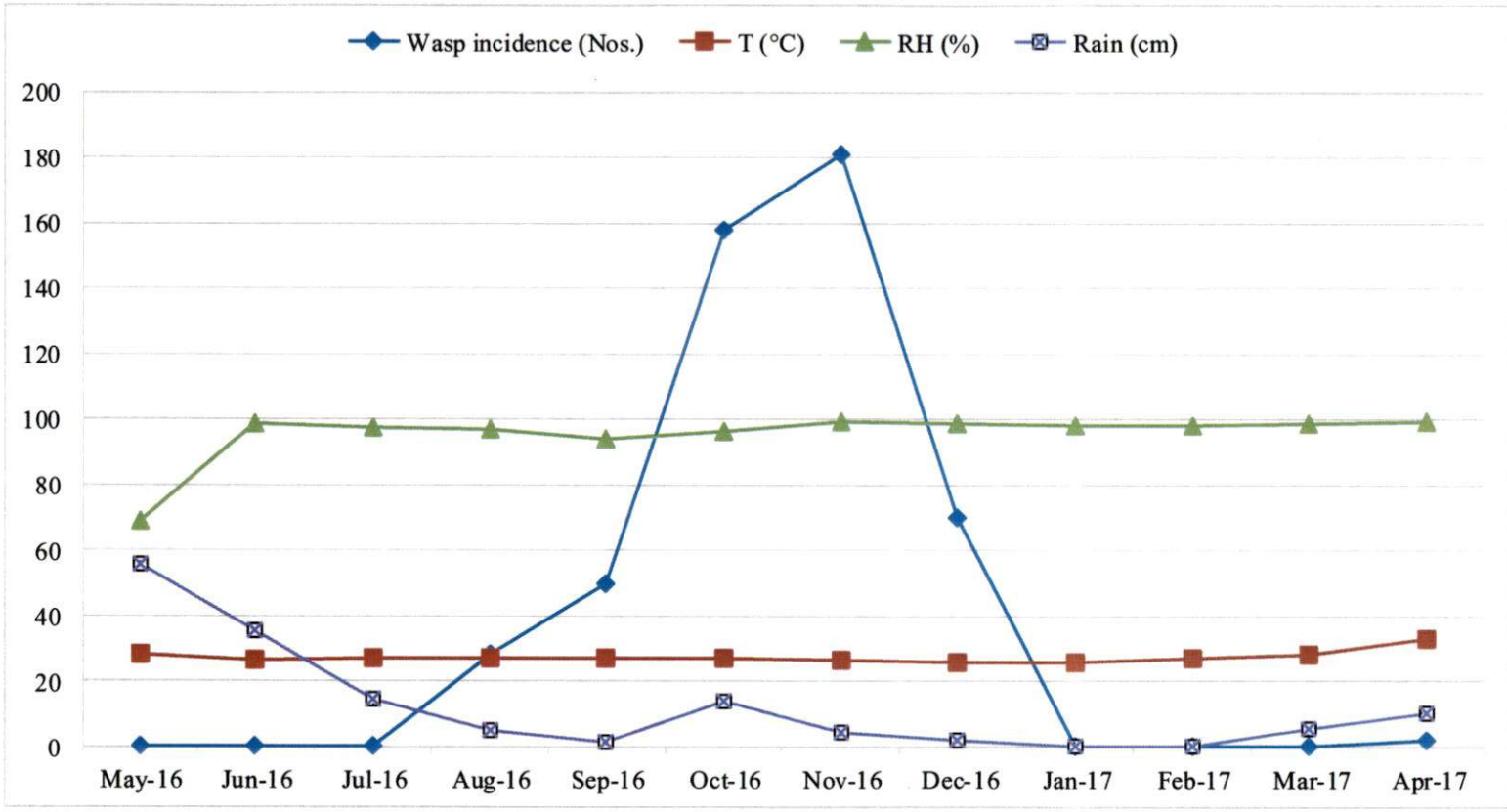

Fig. 3. Influence of weather parameters to the predatory wasp incidence in the Indian bee apiaries (monthly basis)

5.3 ASSESSMENT OF PREDATORY POTENTIAL OF WASP AND DEFENSIVE STRATEGY OF BEES

Out of 52 bees predated by the wasps during the entire period of study, maximum predation was in the 44th week (31st Oct. 2016- 6th Nov. 2017) (18 Nos. day^{-1}). Higher predation might be due to the increase in number of wasps (four wasps at a time) observed during this period. This is in accordance with the findings of Abd Al-Fattah *et al.* (2014) where they observed highest predation in September.

The mode of attack of wasps has been studied by a number of scientists. Koeniger *et al.* (1996) observed that the hawking wasps hovered in front of the entrance facing away from the hive entrance. Similar observations were made by Tan *et al.* (2007) but, contrarily the wasps here were found to seek any cracks and crevices on the hive as a point of entry and also they always faced towards the hive entrance. The *en masse* (four at a time) attack of the wasp in the apiary might be either due to some hive marking pheromone by the hornets which attracts other wasps on the selected hives (Ono *et al.*, 1995) or by the olfactory odours of hive honey, pollen and aggregation pheromone (Couto *et al.*, 2014).

In the present study, the wasp halted on the surface of the hive or near the entrance or alighting board and crept on the hive targeting single bees but, Subbiah and Mahadevan (1957) cited that alighting board of the hive as the only place of halt. The observations immediately after the catch of bees by wasps were similar to that of Koeniger *et al.* (1996), who also observed an abrupt movement downwards and then, a straight flight onto the branches of nearby trees. The bees were mauled and killed using mandibles and carried to their nests.

Meanwhile, the bees also deserted the hives which are endorsed by the findings of Gulati and Kaushik (2004) and Pradeepa and Bhat (2014) who also witnessed an absconding of 25 per cent and 67.50 per cent bee colonies year^{-1}, respectively, due to the attack by wasps. It was also observed that after the absconding of the bees, the wasp entered into the hive and spent ample time inside

the weak colonies, may be to feed on larvae and pupae of bees, as orated by Burgett and Akratanakul (1982) in Thailand.

In the present study on the defensive behaviour of bees, the response of bees on placing an injured wasp at hive entrance was nil as they continued to forage as usual. But, similar experiment by Sharma *et al.* (1979) induced defensive behaviour in bees which resulted in reduced wasps' visits. The null response of bees may be due to the immovability and harmless state of the wasp.

The persistent attack by the wasp was seen to provoke the bees to exhibit a characteristic defense behaviour which, as said by Ono *et al.* (1995) and Koeniger *et al.* (1996), was marked by an increase in the guard bees at hive entrance, clustering and balling of the wasp. Ono *et al.* (1995) also reported that about 500 bees engulfed the wasps and killed them raising the temperature to 47 °C, which was lethal to the wasps but not to the bees. A decline in foraging activities of bees stated by Ken *et al.* (2005) was also observed in the present study due to more bees involved in colony defense. As inferred by Ono *et al.* (1995) the buzzing sound deterred the wasps and prevented it from grabbing on single bees. A failed attempt to prey on the bee resulted in some hundreds of frustrated bees engulf the wasp tightly, almost rendering it immovable. The engulfment of the wasp in the bee ball was reported by Matsuura and Sakagami (1973), Esch and Goller (1991), Koeniger *et al.* (1996), Abrol (2006), Tan *et al.* (2007) and Tan *et al.* (2010).

5.4 FIELD EVALUATION OF BAIT TRAP

The evaluation of bait traps (carbohydrate and protein based) showed that none of the traps were efficient in trapping wasps. Though fermented pineapple + molasses (4:1) bait attracted wasps, a higher number of bees were also attracted. Fermented pineapple juice and molasses was earlier reported efficient in trapping *V. magnifica* in Assam by Rahman and Rahman (1995). In the food preference experiments conducted by Abdel- Gahny *et al.* (2008), though, molasses was regarded as the most desired bait for trapping wasps, Spurr (1996) reported the attraction of non-target species, especially honey bees as a major problem of

carbohydrate based baits. The trapping of bees in pineapple molasses trap completely contradicts the study by Goodwin and Ten-Houten (1991), who showed that molasses strongly repels honey bees. Since both wasps and honey bees belong to Hymenopteran order and are closely related, researchers find it difficult to develop the baits attractive to wasps and not to bees.

Studies by Spurr (1995) revealed raw meat and fish as most attractive to wasps. He stated canned sardine cat-food as the most attractive bait by the wasps. Bacandristsos *et al.* (2006), demonstrated fresh fish as the best bait for *V. orientalis* while, rotten fish and rotten chicken were stated as the best baits by Bhatta and Tamrakar (2011). According to Abd El-Kareim *et al.* (2013), the wasp showed a positive response to the chicken bait. However, laboratory studies of Couto *et al.* (2014) on olfactory attraction of wasps to beef and fish baits showed no response. The fresh odour of the baits failed to capture the attention of wasps' because of which they were not attracted to the baits on the day of its placement. They were seen trapped in the pineapple molasses trap one week after its placement which suggests that the attraction was due to fermentation. The wasps' response to all other traps (protein) was nil. The wasps visit to the apiaries continued even after the placement of baits. Though Bhatta and Tamrakar (2011), has reported the least attraction of honey bees (0.5-0.6) to the rotten fish baits, no bees were trapped in the present study.

Apart from attracting wasps and bees, the baits also attracted some other insects. Proportionally, pineapple + molasses (carbohydrate based) trap comprised of a higher catch of non-target species compared to other (protein based) traps due to the fruity smell and higher volatility. The different insects caught were, fruit moths and butterfly (Lepidoptera), red palm weevil, flower beetle and longicorn beetle (Coleoptera) and other muscoid flies (Diptera). The beef bait attracted the Dipteran flies which laid eggs and bred maggots which fed on it. The chicken bait attracted the weaver ants which almost filled the trap within minutes of bait placement. The fish bait attracted the least insects which mainly included the muscoid flies. No insects were trapped in the control.

Summary

6. SUMMARY

The present study entitled "Seasonal incidence of predatory wasp (*Vespa* spp.) in Indian bee apiaries and evaluation of bait traps" was carried out as four experiments, which includes, documentation of pests of honey bees, estimation of predatory wasp incidence, assessment of predatory potential of wasp and defensive strategy of bees and field evaluation of bait traps at Department of Agricultural Entomology, College of Agriculture, Vellayani during 2015-17. The main objectives were to study the seasonal incidence of *Vespa* spp. in Indian honey bee apiaries, assessment of its predatory potential and evaluation of bait traps against the wasp. The observations were recorded throughout the three beekeeping seasons (lean season, brood rearing season and honey flow season) of the year 2016-17 in the apiaries at Nedumangad, Vilappilshala, Vellayani and Balaramapuram. Ten apiaries with a minimum of ten hives per apiary was selected.

The incidence of honey bee pests' *viz.,* wax moth, spiders, wasps, ants, lizard, honey buzzard and monkey, their symptoms and mode of attack were documented. The damage by larvae of wax moth (*Galleria mellonella* Linnaeus) was observed as galleries and faecal pellets of excreta in the brood comb. The spiders predating on bees were identified as *Argiope anasuja* Thorell, *Hersilia savigyni* Lucas and *Thomisus lobosus* Tikader. The predatory wasp collected from the apiaries was identified as *Vespa tropica* Linnaeus.

Among the ants, the weaver ant, *Oecophylla smaragdina* Fabricius and godzilla ant, *Camponotus compressus* Fabricius predated on the bees whereas, the yellow crazy ant, *Anoplolepis gracilipes* Smith fed on the hive honey. The lizard predating on the bees were identified as *Hemidactylus* sp. The honey buzzard was also found to feed on the brood combs. The monkeys were identified as bonnet macaque (*Macaca radiata* Geoffroy). Hundred per cent infestation by ants was observed in the apiaries which were followed by the wasps (59.86 %) and wax moth (34.87 %). The infestation by the spiders, lizard, honey buzzard and monkey was found to be the least which ranged from 1.32 to 2.63 per cent.

Though pests were observed throughout the year, the frequency of occurrence of pests showed wide fluctuations during different seasons. Among the three beekeeping seasons, the pest attack was highest during the brood rearing season. The wax moths were present almost throughout the year except in June and July whereas, the spiders were observed in and around the hives from August-December and March-April. Ants were seen moving on and near the hives throughout the year. Lizards were observed during September-October and March-April. Honey buzzards and monkeys were occasionally seen in the apiaries. Honey buzzards were witnessed during October-November while, the monkeys raided the apiaries during the dry months of March and April.

Though the predatory wasp was observed in the apiary premises throughout the day, the peak period was found to be from 0930 to 1030 hr (26 visits hr^{-1}) followed by 1430 to 1530 (16 visits hr^{-1}). Maximum wasp incidence was observed during the month of November (181 visits $month^{-1}$), which was followed by October (158 visits $month^{-1}$) and December (70 visits $month^{-1}$).

Of the four locations, the highest wasp incidence (251 visits) was recorded at Nedumangad, followed by Vilappilshala (199 visits). Studies on the seasonal incidence of *V. tropica* revealed that significantly higher wasp population was observed during the brood rearing season (489 visits) than the lean season (28 visits) and honey flow season (8 visits). Correlation studies of the wasp incidence with the weather data (monthly basis) showed a non-significant relationship with all the weather parameters (temperature, relative humidity and rainfall).

Studies on the predatory potential of wasp revealed that the bees were found predated by the wasps only for five weeks *i.e.*, from 41st week to 44th week and also in 48th week. Out of the 52 bees predated by the wasp, maximum predation (18 Nos.) was recorded in 44th week (31st October, 2016 to 6th November, 2016).

Observations on the predatory strategy of wasps showed four distinct behaviour *viz*., arrival, approach, attack and predation. The bees failed to show defense response to the injured wasp placed at the hive entrance and continued their usual foraging behaviour. On facing persistent attack by the wasps, the bees ceased foraging activities, buzzed around and guarded the hive entrance. The frustrated bees were also found to engulf the wasp in a ball of bees, rendering it immovable.

Evaluation of bait traps using carbohydrate based - fermented pineapple + molasses (4:1) (150 g) and protein based - beef (50 g), chicken (50 g), fish (50 g) along with untreated control (water) revealed that no traps were efficient in trapping the wasps. More number of bees (22 Nos.) were trapped in carbohydrate based trap (fermented pineapple + molasses trap), rather than the wasps (0.5 Nos.). Other insects trapped were fruit moths, red palm weevil, long horned beetle, flower beetle and butterfly. The protein based traps (beef, chicken and fish baited) attracted dipteran flies which laid eggs and bred maggots.

With the increase in the practice of beekeeping, incidence of pests of honey bees is also on rise. Among the predators of bees the vespine wasps, *Vespa* spp. has posed a serious threat to the colonies. Since the wasps share the same evolutionary trend as that of the bees, the management of one keeping the other at bay proves to be a difficult task. Keeping in view the diversity of wasps and the benefits provided by predating on crop pests, the present methods of control by burning of wasps nest and use of chemicals were outlawed. Instead the use of baits that trap only the ones acting as pest of bees is preferred. The problem of bait trap arises when bees also get attracted to the baits (carbohydrate) meant for the wasps. Hence, some new combination of baits, volatiles or wasps attracting pheromones have to be developed to solve wasp menace in the apiaries.

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Appendices

APPENDIX I

Standard week (May, 2016 to April, 2017)

Week 18	02-May-16	08-May-16
Week 19	09-May-16	15-May-16
Week 20	16-May-16	22-May-16
Week 21	23-May-16	29-May-16
Week 22	30-May-16	05-Jun-16
Week 23	06-Jun-16	12-Jun-16
Week 24	13-Jun-16	19-Jun-16
Week 25	20-Jun-16	26-Jun-16
Week 26	27-Jun-16	03-Jul-16
Week 27	04-Jul-16	10-Jul-16
Week 28	11-Jul-16	17-Jul-16
Week 29	18-Jul-16	24-Jul-16
Week 30	25-Jul-16	31-Jul-16
Week 31	01-Aug-16	07-Aug-16
Week 32	08-Aug-16	14-Aug-16
Week 33	15-Aug-16	21-Aug-16
Week 34	22-Aug-16	28-Aug-16
Week 35	29-Aug-16	04-Sep-16
Week 36	05-Sep-16	11-Sep-16
Week 37	12-Sep-16	18-Sep-16
Week 38	19-Sep-16	25-Sep-16
Week 39	26-Sep-16	02-Oct-16
Week 40	03-Oct-16	09-Oct-16
Week 41	10-Oct-16	16-Oct-16
Week 42	17-Oct-16	23-Oct-16
Week 43	24-Oct-16	30-Oct-16
Week 44	31-Oct-16	06-Nov-16
Week 45	07-Nov-16	13-Nov-16
Week 46	14-Nov-16	20-Nov-16
Week 47	21-Nov-16	27-Nov-16
Week 48	28-Nov-16	04-Dec-16
Week 49	05-Dec-16	11-Dec-16
Week 50	12-Dec-16	18-Dec-16
Week 51	19-Dec-16	25-Dec-16
Week 52	26-Dec-16	01-Jan-17
Week 01	02-Jan-17	08-Jan-17
Week 02	09-Jan-17	15-Jan-17
Week 03	16-Jan-17	22-Jan-17

Week 04	23-Jan-17	29-Jan-17
Week 05	30-Jan-17	05-Feb-17
Week 06	06-Feb-17	12-Feb-17
Week 07	13-Feb-17	19-Feb-17
Week 08	20-Feb-17	26-Feb-17
Week 09	27-Feb-17	05-Mar-17
Week 10	06-Mar-17	12-Mar-17
Week 11	13-Mar-17	19-Mar-17
Week 12	20-Mar-17	26-Mar-17
Week 13	27-Mar-17	02-Apr-17
Week 14	03-Apr-17	09-Apr-17
Week 15	10-Apr-17	16-Apr-17
Week 16	17-Apr-17	23-Apr-17
Week 17	24-Apr-17	30-Apr-17

APPENDIX II

Monthly weather data during the period of study, May, 2016 to April, 2017

Month	Temperature (°C)	RH (%)	Rain (cm)
May-16	28.35	69.16	56.02
Jun-16	26.48	98.48	35.55
Jul-16	27.12	97.76	14.83
Aug-16	27.33	97.04	5.18
Sep-16	26.83	93.77	1.51
Oct-16	27.35	96.52	13.68
Nov-16	26.37	99.58	4.61
Dec-16	25.88	98.48	2.20
Jan-17	26.14	98.36	0.36
Feb-17	27.07	98.26	0.00
Mar-17	28.48	98.72	5.71
Apr-17	33.29	99.24	10.35

SEASONAL INCIDENCE OF PREDATORY WASP (*Vespa* spp.) IN INDIAN BEE APIARIES AND EVALUATION OF BAIT TRAPS

by

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8. ABSTRACT

The study entitled "Seasonal incidence of predatory wasp (*Vespa* spp.) in Indian bee apiaries and evaluation of bait traps" was carried out in the Department of Agricultural Entomology, College of Agriculture, Vellayani during 2015-17. The objective was to study the seasonal incidence of *Vespa* spp. in Indian honey bee apiaries, assessment of its predatory potential and evaluation of bait traps against the wasp. The observations were recorded throughout the three beekeeping seasons (lean season, brood rearing season and honey flow season) of the year 2016-17 in the apiaries at Nedumangad, Vilappilshala, Vellayani and Balaramapuram.

The incidence of honey bee pests' *viz.* wax moth, spiders, wasps, ants, lizard, honey buzzard and monkey, their symptoms and mode of attack were documented. The damage by larvae of wax moth (*Galleria mellonella* Linnaeus) was observed as galleries and faecal pellets of excreta in the brood comb. The spiders predating on bees were identified as *Argiope anasuja* Thorell, *Hersilia savigyni* Lucas and *Thomisus lobosus* Tikader. The predatory wasp collected from the apiaries was identified as *Vespa tropica* Linnaeus. Among the ants, the weaver ant, *Oecophylla smaragdina* Fabricius and godzilla ant, *Camponotus compressus* Fabricius predated on the bees whereas, the yellow crazy ant, *Anoplolepis gracilipes* Smith fed on the hive honey. Cent per cent infestation by ants were observed in the apiaries which was followed by the wasps (59.86 %) and wax moth (34.87 %). The infestation by the spiders, lizard (*Hemidactylus* sp.), honey buzzard and monkey (*Macaca radiata* Geoffroy) was found to be the least.

Though the predatory wasp was observed in the apiary premises throughout the day, the peak period was found to be from 0930 to 1030 hour (26 visits hr^{-1}), which corresponds to the active foraging hours of honey bees. Maximum wasp incidence was observed during the month of November (181 visits). Of the four locations, the highest wasp incidence (251 visits) was recorded at Nedumangad which may be due the hilly areas and thick vegetation in

that region. Studies on the seasonal incidence of *V. tropica* revealed that significantly higher wasp population was observed during the brood rearing season than the lean season and honey flow season. Correlation studies of the wasp incidence with the weather data (monthly basis) showed a non-significant relationship with all the weather parameters (temperature, relative humidity and rainfall).

Studies on the predatory potential of wasp revealed that the bees were found predated by the wasps only for five weeks *i.e.*, from 41st week to 44th week and also in 48th week. Out of the 52 bees predated by the wasp, maximum predation (18 Nos.) was recorded in 44th week (31st October, 2016 to 6th November, 2016). Observations on the predatory strategy of wasps showed four distinct behaviour *viz.*, arrival, approach, attack and predation. The bees failed to show defense response to the injured wasp placed at the hive entrance and continued their usual foraging behaviour. On facing persistent attack by the wasps, the bees ceased foraging activities, buzzed around and guarded the hive entrance. The frustrated bees were also found to engulf the wasp in a ball of bees, rendering it immovable.

Evaluation of bait traps using carbohydrate based - fermented pineapple + molasses (4:1) (150 g) and protein based - beef (50 g), chicken (50 g), fish (50 g) along with untreated control (water) revealed that no traps were efficient in trapping the wasps. More number of bees (22 Nos.) were trapped in carbohydrate based trap (fermented pineapple + molasses trap), rather than the wasps (0.5 Nos.). Other insects were also trapped.

The predation of honey bees by the wasp recorded in the apiaries was 59.86 per cent with peak incidence during the month of November. Significantly higher wasp population was observed during the brood rearing season (September - December) of honey bees. Maximum predation of bees (18 Nos.) was observed in the 44th week. Since no bait traps were found efficient in trapping the wasps, a new method has to be developed against the wasp.