FORAGING ECOLOGY AND CONTROL OF WASPS ASSOCIATED WITH HONEY BEES

THESIS

By

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HIMACHAL PRADESH KRISHI VISHVAVIDYALAYA

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CERTIFICATE I

This is to certify that the thesis entitled **"Foraging ecology and control of wasps associated with honey bees"** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science (Agriculture)** in the subject of **Entomology** of Himachal Pradesh Krishi Vishvavidyalaya, Palampur is a bonafide research work carried out by **Mr. Virender Kumar** son of Shri Gurbachan Dass under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been fully acknowledged.

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Place : Palampur
Dated : the 26th November, 1998

CERTIFICATE II

This is to certify that the thesis entitled **"Foraging ecology and control of wasps associated with honey bees"** submitted by **Mr. Virender Kumar** son of Shri Gurbachan Dass to the Himachal Pradesh Krishi Vishvavidyalaya, Palampur in partial fulfilment of the requirements for the award of the degree of **Master of Science (Agriculture)** in the subject of **Entomology** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

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MY REVEREND GRAND FATHER

LATE SH. KARAM CHAND JI

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(VIRENDER KUMAR)

Place : Palampur
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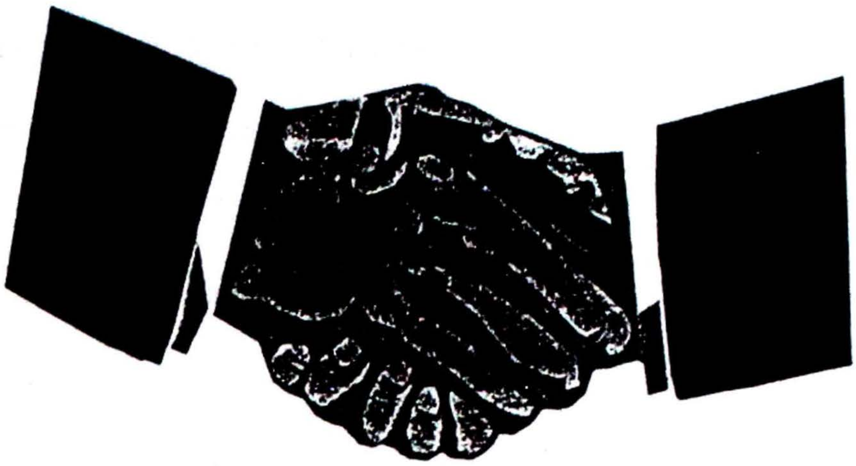


INTRODUCTION

INTRODUCTION

Honey is the most appreciated and nutritive bee product rich in carbohydrates having great potential to overcome malnutrition in developing countries. In mid hills and valley areas of Himachal Pradesh, there is immense potential for beekeeping owing to suitable climate and abundance of wild and cultivated bee flora. But, for the development of bee industry, predatory wasps are the main hindrance to beekeeping. In Himachal Pradesh honey yield per colony is very low i.e. 8-9 kg (Patyal, 1995) as compared to 15-20 kg in advanced countries (Shinde and Phadke, 1995).

Honey bees are endangered by a variety of parasites and predators. Amongst the predators, wasps are the most important and pose serious threat to bee industry. They are predaceous by nature and feed on bees and other insects. They catch the honeybees in the apiary either by hovering around the bee hives or by sitting at the hive entrances. Some of the *Vespa* species are bold enough to catch the honeybees directly from the combs. Wasps after macerating the bees make their pellets and take them to their nests to feed their young ones. In Himachal Pradesh alone 20-25 per cent of the colonies are deserted annually due to predatory activity of the wasps (Adlakha *et al.*, 1974). In this region, *Vespa* species are the most frequent visitors in the apiaries (Singh, 1962; Sharma and Raj, 1988). Wasps besides killing, rob them of their eggs, brood and honey reserves. Their attack coincides particularly with the floral dearth and other stresses during monsoon season (Sharma *et al.*, 1985) and the deserted colonies get perished due to starvation.

Wasps also catch and kill the honey bees under field conditions while foraging for nectar and pollen on different crops (Abrol, 1994; Mishra, 1995). The stinging behaviour of wasps makes the control measures more difficult either due to wasp fear or inaccessibility of the nest.

There are various recommendations for the control of wasps such as destruction of individual female wasps in the early spring, flapping, killing with kerosene torches or chemical spraying; but the existing recommendations are either labour intensive, time consuming or sometimes practically infeasible. Therefore, keeping in view the seriousness of the problem, the present investigations were undertaken with the following objectives:

- To identify the different species of wasps attacking the honey bees;
- to study the foraging ecology of wasps and defensive behaviour of honey bees against them; and
- to evaluate different methods for wasp control.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Wasps are social insects and build paper nests in cavities of trees, walls or hang them down from the tree-trunks. Some species are ground dwellers. Inspite of the magnitude of the problem posed by the wasps in apiaries, very few studies have been carried out on 'Foraging ecology and control of wasps associated with honey bees'. The available literature on these aspects is reviewed below:

2.1 DISTRIBUTION

Several species of wasps have been associated with honey bees in India and abroad. In France, although seven species were found, but *V. germanica, V. crabro* and *V. vulgaris* were reported to be more injurious in apiaries, orchards and vineyard (Feytaud, 1927). Mellor (1928; 1929) concluded that *V. orientalis* is a serious pest of Egyptian apiaries. In Japan bee industry is threatened by *V. mandarinia* (Tokuda, 1928; Sakagami and Matsuura, 1972). For some years, the *V. orientalis* plagued the bee industry, especially in Fayoum region of Egypt and has been recorded as a serious pest of honey bees in Palestine and Israel (Anonymous, 1933; Macrovitch, 1952; Ibrahim and Mazeed, 1967). Taylor (1939) reported the two wasps, *Palarus latifrons* and *Philanthus didema* attacking honey bees in South Africa. In Indian hills and plains, *V. magnifica* and *V. auraria* are the most important wasps in apiaries (Dave, 1943). *V. basalis* and *V. auraria* have been reported from Punjab, whereas, *V. cincta* was recorded in

Madras (Raw, 1954). Kshirsagar and Mahindre (1975) reported *V. orientalis* (L.), *V. cincta* (F.), *V. auraria* (Smith), *V. ducalis* (Smith), *V. basalis* (Smith) and *V. magnifica* (Smith) predatory on honey bees in plains and hills. From Kangra district of Himachal Pradesh, *V. mandarinia, V. tropica, V. velutina* and *V. basalis* and *V. orientalis* are known to attack *A. mellifera* and *A. cerana* colonies forcing them to abscond particularly during monsoon (Sharma *et al.*, 1985; Sharma and Raj, 1988). Rajgopal *et al.* (1997) listed *V. cincta, V. orientalis, V. mandarinia, V. auraria, V. basalis, V. magnifica, V. flavicep* and *V. velutina* from various parts of the country causing severe losses to the beekeeping industry. According to Vankata Rau (1945) yellow wasps (*V. auraria*) are real menace to bee industry in India.

2.2 FOOD SOURCES

Besides predating upon honey bees wasps have been reported to damage various summer fruits to obtain their food from Southern and Eastern parts of Mediterranean basin, South-East and Central Asia, Egypt, Sahara and in Ethiopia (Ishay *et al.*, 1967).

V. tropica (L.) (*cincta* F.) has also been observed causing excessive damage to half and full ripe grapes in Mysore by Viswanath *et al.* (1970). However, Sharma *et al.* (1979) reported more preference of *V. auraria, V. cincta* and *V. magnifica* for decaying fish and meat whereas, *V. basalis* preferred rotten apples. These wasps are also known to forage to fish/meat to feed their larvae (Caron and Schaefer, 1986).

Mishra *et al.* (1989) observed 5.5-8.8 wasps per 15 minutes foraging on pear, peach and apple, and also found their attraction to mango and plum. They reported *V. auraria* as the most frequent visitors on fruit baits (14.63 wasps/15 min) followed by *V. basalis* (6.16 wasps/15 min). Patt *et al.* (1997) reported that nectar odour attracts and stimulates the wasps on flowers of dill *(Anetham graveolans)*, fennel *(Foeniculum vulgare)* and corianoer (*Curiandrum sativa*).

2.3 FORAGING BEHAVIOUR

2.3.1 Foraging behaviour of wasps under an apiary conditions

Ghosh (1924) reported *V. auraria* to catch honey bees on wings, whereas, *V. cincta* and *Vespula pensylvanica* dismember in and out going bees at the hive entrance. Mutto (1949) reported social wasps as major pests from India. *V. magnifica* has been reported to be very dangerous in hilly districts of India (Anonymous, 1950), raiding the hive in great force of 50-100 individuals exterminating the colony in a matter of hours. *V. cincta* has been reported to frequent bee-boards of *A. cerana* during cool and cloudy mornings from June to December when the breeding activity of the bees is low and the wasps further weaken the colonies in South India (Subbiah and Mahadevan, 1957). In France, wasps are most numerous from August to early November when the bees population is at a low level due to adverse natural conditions (Ibrahim and Mazeed, 1967). In USSR, Atakishiev (1971) reported *V. orientalis, V. vulgaris* and *V. crabro* causing severe damage to the honey bee colonies in spring and autumn, and recorded as many as 300 *V. crabro* wasps per hour flying from nests and attacking the hive in groups. In South Japan, *V. mandarinia* has been reported to kill 5,000-25,000 bees out of the total population of 15,000-30,000 per bee hive and only two wasps died during encounter (Matsuura and Sakagami, 1973). The wasps of *Vespula* species gets activated at lower temperature than the honey bees, enter the hive in autumn when the bees are helpless in defending themselves (Davis *et al.*, 1975). Brar *et al.*, (1985) observed *V. orientalis* visiting the bee colonies from July to December having 21.3-63.3 wasps per apiary in August-October attaining a peak in September. Diurnal activity was maximum (30-51 wasps) between 1200-1400 hours during peak activity. In North Island, wasps caused more problem during spring build up than in South Island, totally destroying 8 to 9 per cent of colonies in the two seasons (Clapperton *et al.* 1989).

Sihag (1992a) reported *V. orientalis* visiting an *A. mellifera* apiary from June to November initially predating upon guard bees at hive entrances, and later invading and robbing the weak colonies after mid July. Between June to mid July and mid July to October on an average 286 and 515 bees were caught by wasps and the corresponding wasp population was reported to be 7.5 and 13.5, respectively (Sihag, 1992b). Coelho and Hoagland (1995) could observe only three *V. germanica* flying off with whole honey bees but other wasps chewed off body parts until they could fly with a head, thorax and abdomen. Srivastava *et al.* (1995) studied the predatory behaviour of different wasps and reported *V. magnifica* and *V. auraria* to be more serious to *A. mellifera* colonies taking 1.2-3.9 seconds and 15.3-21.2 seconds per catch, respectively.

2.3.2 Foraging behaviour of wasps under field conditions

Wasps are not only preying upon bees in the apiary but they also do so under field conditions. Sihag (1992a) reported *V. orientalis* capturing honey bees foraging on flowers from May to December. On an average 181 *A. mellifera* per hectare per day were predated at the foraging site in addition to 726 other bees viz. *A. florea, A. dorsata* and solitary bees (Sihag, 1992b).

2.4 DEFENSIVE BEHAVIOUR OF HONEY BEES AGAINST WASPS

Singh (1972) studied the defensive behaviour of *A. cerana* against a predatory hornet *V. velutina* and reported highest bee mortality at low wasp intensity but at higher wasp intensity bee mortality was less due to an organised bee defense. Sharma *et al.* (1979) induced defensive behaviour in honey bees by providing injured wasps at hive entrance and reported trained colonies three and half times more active than untrained in knocking down the wasps. Collins and Kobasek (1982) suggested three types of stimuli (a synthetic alarm pheromone, a marble shot at a colony and visual tactual) eliciting four discrete steps of defensive behaviour by alerting, activating, attracting and culminating. Collins and Rinderer (1986; 1991) reported the volatile primer pheromones from combs to induce defensive behaviour (alerting, activating, attracting and attacking) in Africanised bees. They also studied the genetics of defense in honey bees and concluded that the trait of defensive behaviour is polygenic. Matsuura (1988) found that *A. mellifera* has not any effective defense against *V. mandarinia* and recommended artificial protection in the habitat of hornets. On the other hand, *A cerana* has developed two effective defensive strategies which are not found in *A. mellifera*; one being the absence of solitary counter attacks and the other an effective form of mass counter attack (Matsuura and Yamane, 1990). This species has also been reported to resist the wasp attack by shimmering behaviour or movements, forming tight ball around the wasp and killing them by suffocation or raising body temperature of wasp (Singh, 1972; Shah and Shah, 1991; Abrol, 1994; Ono *et al.*, 1995). *A. mellifera* bees also tend to form ball but are not able to kill the wasps due to failure in raising the body temperature to lethal levels.

Matsuura and Yamane (1990) reported *A. cerana* as a unsuitable target when compared with *A. mellifera* and other Vespine wasps showing more preference to attack *A. mellifera*. Similarly, Shah and Shah (1991) reported more preying preference for *A. mellifera* (24 bees/30 min.) as compared to *A. cerana* (1 bee/30 min.).

2.5 CONTROL

2.5.1 Baiting

Wafa *et al.* (1969) tested seven toxic honey baits to attract wasps and found 'DDT + lindane + honey' and 'malathion + honey' bait best under laboratory and at the nest site, respectively. Sharma *et al.* (1979) suggested the use of baits as potential control measure and emphasized the need to be fully explored. Donovan (1985) obtained best control of *Vespula germanica* with mirex (0.5-1.0%) after mixing it with minced fish, placing it at a number of sites in high pest density areas. Sharma *et al.* (1985) fixed aluminum phosphide powder on the abdomen of wasp and set them free to go back to their nests in order to kill more wasps. Wang *et al.* (1985) obtained good control of wasps by smearing the wasp with 6 per cent huichaoling dust @ 1-2 gm per wasp.

However, Mishra *et al.* (1989) developed the capsule cup technique and achieved good control at Solan (H.P.). Fenitrothion + gur @ 110 mg/capsule/wasp was fixed with the help of quick fix on the thorax and these wasps were sent back to their nests. They also observed that a load of 110 mg poison bait could easily kill 30-35 wasps. Spurr (1991) tested Sodium monofluoroacetate at 0.1-1.0 per cent against wasp by mixing it with caned sardine in aspic jelly as a bait and got 17-89 per cent reduction in the wasp traffic. Later on, Spurr and Elliott(1996) tested Finitron (Sulfluramid) in sardine bait successfully against *V. vulgaris* and *V. germanica* in New Zealand. Donovan (1992) suggested the possibility to trap and kill the foraging wasps with baits to weaken their nests and control them. Akre and Mayer (1994) discussed different methods of wasp control but suggested toxic baits as most efficient and the single best technique in controlling hornets since colonies need not to be located to effect the control. Taber (1987) also highlighted that most effective control can be achieved by ensuring strong colonies through good management practices.

2.5.2 Trapping

Mellor (1928;1929) recommended trapping as one of the methods for the control of predatory wasps in apiary. Trapping of wasps in apiary is very helpful in reducing the frequency of their attack. A trap of empty petrol tin was prepared by piercing holes in which fine mesh cones of an opening of 1/2" diameter, were inserted and used for trapping wasps in apiary (Anonymous, 1950). Ibrahim and Mazeed (1967) tried seven types of traps by using honey as bait and found wooden trap to be more efficient in trapping wasps followed by 'Kerosene can trap'. A modified wasp trap was used by Wafa *et al.* (1968) in which honey combs were used as baits and distributed round the apiary to attract the wasps and when attracted, the combs were shaken into the traps and the door was quickly shut. Using this method, 23,900 and 13,095 wasps/trap were caught in October, 1962 and October, 1963, respectively. Rogers and Lauret (1968) designed a standard yellow jacket trap based on fly trap and observed a catch of 4,000 yellow jackets in 3 days. The trap effectiveness is based on strong tendencies of yellow jackets to seek entrance at the bottom of such containers and escape in an upward direction, especially toward an over head light source. Twelve synthetic attractants were tested by Davis *et al.* (1975) against *Vespula pensylvanica* in trap and found heptyl butyrate and octyl butyrate as most effective attractants for trapping the wasps. In total, 4,03,350 wasps were trapped but only 11 honey bees and 6 leaf cutter bees were caught in 3,456 concurrent tests.

Mac Govern *et al.* (1970) also tested 293 saturated organic esters and found octyl and nonyl esters of pivalic and butyric acids 2 to 2.5 times more effective than the standard, 2,4-hexadienyl butyrate. Kshirsagar (1971) developed a modified design of wasp trap given by Wafa (1956) and found it effective in the apiaries, especially during the active period of queen wasps after hibernation. By using artificial attractants in traps, Mac Donald *et al.* (1973) collected 6 species of Vespula by using heptyl butyrate as artificial attractant. *V. atropilosa* and *V. pensylvanica* were trapped in large numbers. Edwards(1977) tested a trap baited with natural ginger syrup in a sweet factory and a backery in the UK collecting more than 50,000 wasps and bees in 61 days but the traps could alleviate the wasp problem instead of controlling them.

Delmotte and Mathot (1983) compared different coloured plastic traps in plum and apple orchards and found more attraction of wasps towards green traps. In addition to insecticides, sucrose solution was also found useful for trapping and killing of wasps (Muzaffer and Ahmed, 1986). Mayer *et al.* (1987) hanged a fish just over bucket or can of water with detergent to trap yellow jackets. They also recommended the heptyl butyrate trap commercially available as 'jacket trap' around the bee yard to catch more number of wasps. Maniog and Patetta (1987) found the use of bottle traps containing 1 per cent solution of hydrolysed protein as most convenient means of control. Similarly, Shah and Shah (1991) used a mixture of fermented honey and water (50:50) in glass jars in apiary and captured 11,483 hornets in 10 days during October, 1988. Christie (1994) tested five bait traps against wasps in Rhode Island, U.S.A. and caught *Vespula germanica, V. maculifrans* and *V. flaviopilosa*. At Palampur, Thakur and Kashyap (1996) tested lure trap along with bees protectors in apiary against *V. magnifica* and observed good luring with sucrose or fermented honey. The trapped wasps were killed by insecticidal baits (Baygon + sucrose; Baygon + fermented honey) kept inside the traps.

2.5.3 Bees protectors

Queen gate of 5" x 2" was found useful in reducing the wasp attack in apiary (Dave, 1943). Elimination of the alighting board by pushing the body of hive forward, thereby leaving no alighting space for bees or the wasps, considerably reduced the wasp attack (Subbiah and Mahadevan, 1957). Mayer *et al.* (1987) recommended 'screen entrance reducer' to discourage wasps from gaining entry into a hive. Srivastava *et al.* (1995) developed a new barrier device "Bee-Wasp Protector" which was found effective in protecting bees from wasp attack at the hive entrance. At Palampur, Thakur and Kashyap (1996) used bees protectors in *A. cerana* colonies to discourage the *V. magnifica* activity at the hive entrances.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present studies on "Foraging ecology and control of wasps associated with honey bees" were carried out at the apiary of Department of Entomology, Himachal Pradesh Krishi Vishvavidyalaya, College of Agriculture, Palampur and also at farmer apiary in Una district during August, 1996 to December, 1997. The geographical location of the campus is 32° 6' N latitude, 76° 3' E longitude and 1300 meters altitude. During the period of observations, the experimental apiary at Palampur comprised of the two hive bee species but with a predominance of *Apis mellifera* colonies. The general methods and techniques followed for conducting these investigations are described in this chapter.

3.1 COLLECTION AND IDENTIFICATION OF WASPS

Different species of wasps attacking honey bee colonies were collected from various locations in Una (Jhalera, Khanpur and Takka) and Kangra (Palampur and Sarkari Sidhpur) districts from August, 1996 to December, 1997. Species were got identified from IARI, New Delhi.

3.2 SURVEY OF FOOD SOURCES

Observations were recorded on different wasps feeding on flower nectar, ripe fruits, tree sap, insects and other products at Palampur and Una areas during August, 1996 to December, 1997. In case of ripe fruits observations were recorded under field and market conditions.

3.3 FORAGING BEHAVIOUR OF WASPS UNDER APIARY CONDITIONS

3.3.1 Foraging population

Observations on the foraging population of wasps were recorded in different seasons during, 1997 viz., summer, rainy and autumn seasons in the departmental apiary at Palampur. Population was recorded by counting the number of wasps visiting a hive per 30 minutes, replicated four times, at the start of each observational hour (0900-1700 hrs) at weekly interval. Later on diurnal as well as weekly trends in the foraging population of wasps were worked out for different seasons. Data on temperature and relative humidity were also recorded with the help of thermo-hygrometer during the period of observations.

3.3.2 Predation behaviour of wasps under apiary conditions

Time spent per catch : Observations were recorded on time spent per catch of different species in between 0900-1000, 1200-1300, and 1500-1600 hours and were replicated ten times. Such observations were recorded for three sunny days at Palampur during October, 1996. In case of *Vespa auraria* time spent per catch refers to the time when a wasp started hovering near the hive entrance and till it catches a bee. Whereas in case of *Vespa magnifica* it refers to the time gap in between the two bees predated at the entrance.

Predation success : Predation success was worked out at different day hours (0900-1000, 1200-1300 and 1500-1600 hrs) by using the following formula:

$$\text{Predation Success (\%)} = \frac{\text{Number of wasps catching honey bees/unit time}}{\text{Total number of wasps visiting a hive}} \times 100$$

3.4 FORAGING BEHAVIOUR OF WASPS UNDER FIELD CONDITIONS

Observations were recorded on different insects viz., honey bees, wasps and flies, visiting the flowers of toria (*Brassica campestris* var. *toria*), pajja (*Prunus puddum*) and bottle brush (*Callistemon lanceolatus*) at Palampur during 1997-98. For recording the data in case of toria 1 m^2 area was randomly selected at three different places in the field. In case of trees, approximately 1 m^2 area was selected on three different sides of a plant and the data were recorded on different insect visitors for 15 minutes. Such observations were recorded on 7 sunny days on toria, pajja and bottle brush during October-November, September and April, respectively. The number of honey bees predated by *Vespa auraria* were also noted to find out the predation potential of wasps under field conditions.

3.5 FREQUENCY AND DURATION OF FORAGING TRIPS

Foraging trips of *Vespa auraria* were recorded at Palampur, during September-October, 1997 by capturing and marking the wasps. Forager wasps were caught on September, 22 with the help of insect collection net in *Apis mellifera* apiary and the observations were recorded from September, 23. These wasps were transferred to insect cages (16x15x15 cms) and put in deep freeze for 8-10 minutes in order to facilitate markings on their different body parts such as head, thorax, abdomen and wings as a sign of identification. Lead marker of Kuretake Company, Japan was used to mark the insects. More than 10 wasps were marked and released. Data were taken on the number of foraging trips undertaken per day by individual wasp from 0700-1800 hours.

Time spent by individual wasp in between the two foraging trips was also recorded.

3.6 DEFENSIVE BEHAVIOUR OF HONEY BEES

Defensive behaviour of *Apis cerana* and *Apis mellifera* was studied in a mixed apiary at Palampur during September, 1997 by taking following observations:

i) Number of wasps visiting per bee hive

ii) Number of bees captured per bee hive

iii) Number of wasps left without honey bee per bee hive

These observations were recorded in between 1000-1100 hours for 5 sunny days.

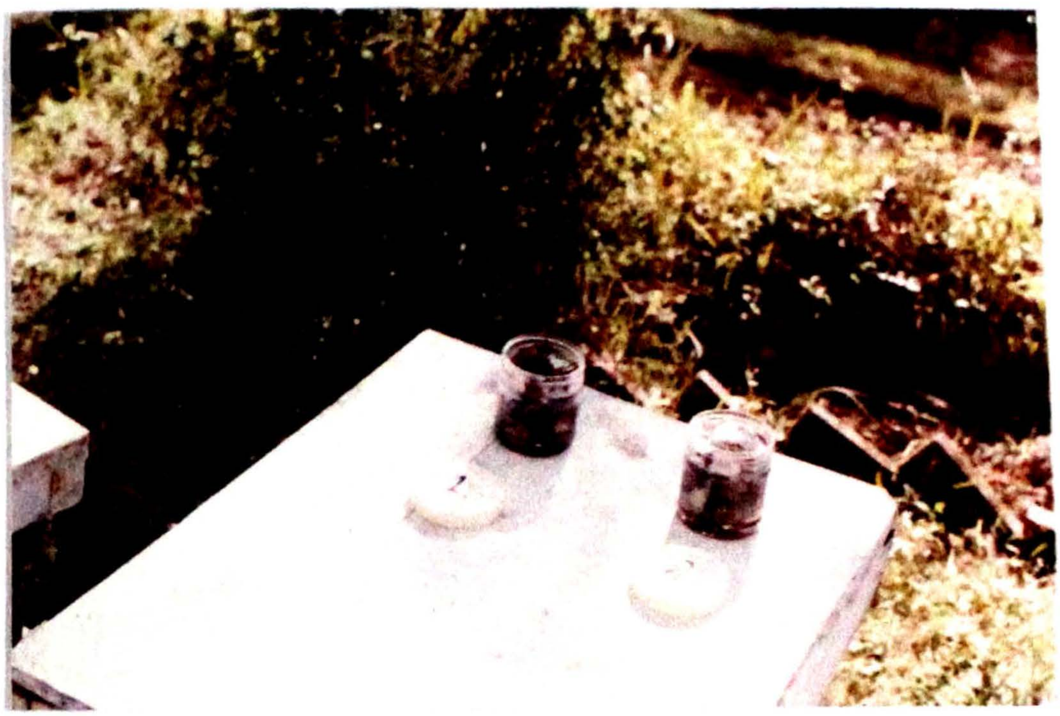
3.7 CONTROL

Control experiments were conducted by using baits, traps and bee protectors as described below:

3.7.1 Baiting

Two preparations/baits viz., meat and fish were evaluated in combination with carbaryl (Sevin 50WP), Nuvan (dichlorovas 76EC) and Baygon (propoxur 2%). The poisoned baits were prepared by dipping them in 0.05 per cent solution of carbaryl and Nuvan for 2 hours. In case of Baygon 15 gm of insecticide was powdered and mixed in 600 ml of water before dipping the meat or fish for 2 hours. Before conducting the experiment under apiary condition, the concentration giving cent per cent mortality of wasps was standardised under laboratory conditions by mixing insecticides with 'gur'. These baits were kept over the bee hives in plastic jars (Plate 1). In each jar, 100 gm of

Plate No. 1 Plastic jars containing poison baits



meat/fish was used. Fresh baits were kept daily for 3 days Observations were recorded on the number of wasps attracted per jar in order to find out most suitable baits. Each treatment was replicated thrice.

3.7.2 Plastic Wet Trap

Plastic wet trap developed during 1996 (Anonymous, 1997) was further evaluated in the departmental apiary during, 1997. Three traps (Plate 2) were kept in the *Apis mellifera* apiary on October, 2 and the observations were recorded on the number of wasps killed after every three days and fresh meat bait was provided inside the trap after every 3 days.

3.7.3 Bee Protectors

Two bee protectors (BP-I and BP-II) as used by Thakur and Kashyap, (1996) were evaluated to protect *Apis mellifera* bees from *Vespa auraria* and *Vespa magnifica* with little difference in size and gap of metal wires. Size of bee protector was 25x10x10 cms. In BP-I (Fig. 1) there was a gap of 6 mm in between two metal wires and in BP-II (Fig. 2) this gap was 7 mm. Both these protectors were fixed at the hive entrances of *Apis mellifera* colonies during October, 1996. The observations (15-30) were recorded (5-10 minutes) on the number of honey bees predated by *Vespa auraria* and *Vespa magnifica* in between 1000-1200 hours daily for 5 sunny days in such protected v/s unprotected colonies.

STATISTICAL ANALYSIS

All the data pertaining to predation success, defensive behaviour, relative abundance of insects and their predation by wasps were statistically analysed by

Plate No. 2 Plastic wet traps containing water + teepol and showing triangular wasp entry hole (2.5 x 2.5 x 2.5 cm)

A - Opened trap showing bait position on the inner side of a lid fixed with metal wire

B - Trap as used with lid closed


A
B

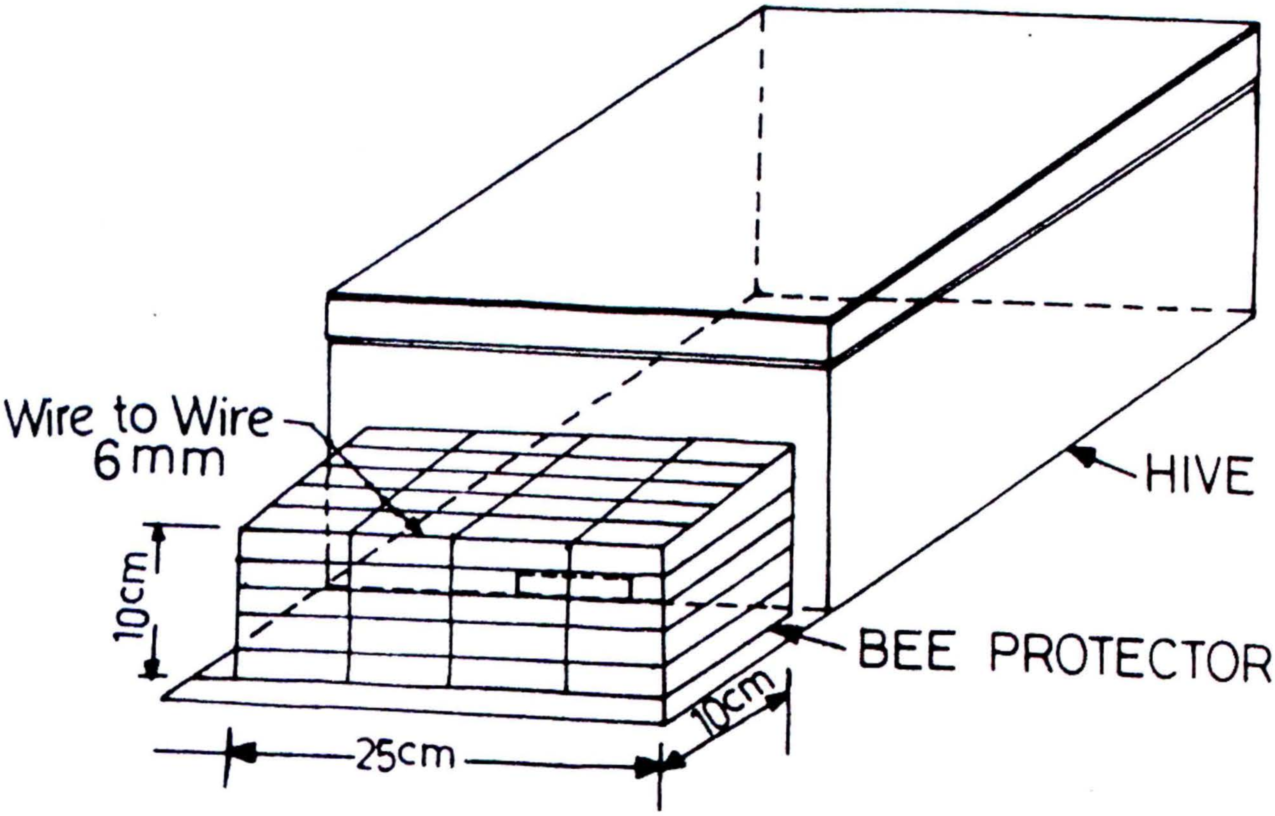


Fig.1 Line diagram showing Bee Protector-I

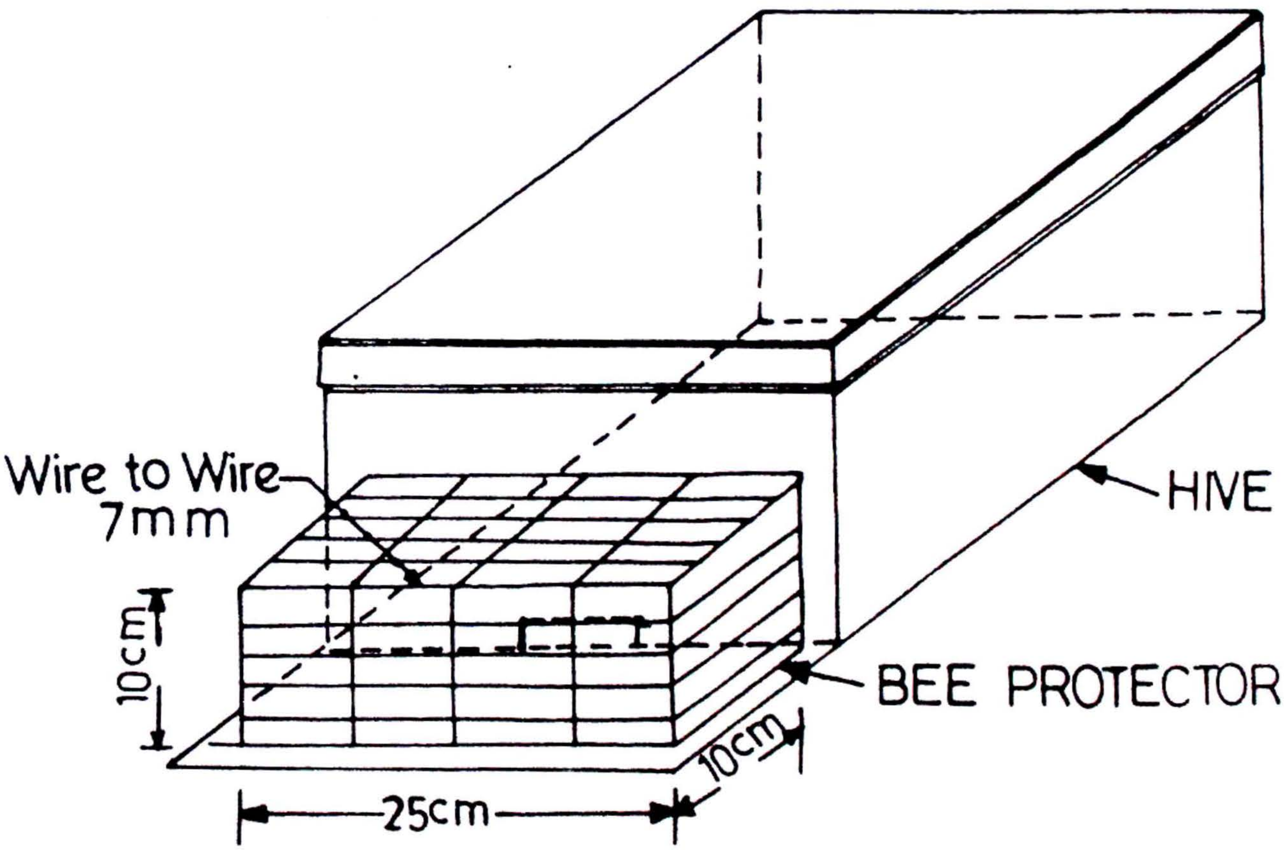


Fig.2 Line diagram showing Bee Protector-II

using factorial randomized block design, whereas, the data on baiting, time spent per catch were analysed by factorial complete randomized design. The data on trap catch, frequency and duration of foraging trips were analysed by randomized block design. The relationship of wasp population with temperature and relative humidity were worked out by calculating linear correlation coefficient (r).

RESULTS

RESULTS

The results obtained during the investigations carried on "Foraging ecology and control of wasps associated with honey bees" are presented in this chapter.

4.1 DIFFERENT SPECIES OF WASPS

Six species of wasps viz. *V. auraria* (Smith), *V. basalis* (Smith), *V. cincta* (F.), *V. magnifica* (Smith), *V. orientalis* (L.) and *Vespa* sp. were collected at Palampur and Una areas (Table 1 & Plate 3). At Palampur, *V. orientalis* was not present and *V. magnifica* was absent at Una. At Palampur, *V. magnifica* and *V. auraria* were the two predominant wasps frequently observed in apiaries causing huge losses both to *A. mellifera* and *A. cerana* bees. However, rest of the species were occasionally visiting the apiaries. At Una, *V. auraria*, *V. cincta* and *V. orientalis* were dominant and seriously damaged *A. mellifera* colonies.

4.2 FOOD SOURCES

Different food sources of wasps were identified by conducting field and market surveys at regular intervals (Table 2). In all 22 food sources of different wasps were identified. *V. magnifica* was recorded feeding only on 5 food sources viz. *A. mellifera, A. cerana*, 'gur', fish and meat. *V. auraria* was seen feeding on all the food sources including flower nectars, ripe fruits (Plate 4), tree saps, insects and other products. Tree sap was found good food source for the wasps during autumn season. Three species viz. *V. auraria*, *V. cincta* and *V.*

Plate No. 3 Different species of wasps

Vespa sp.

Vespa cincta *Vespa orientalis*

Vespa auraria *Vespa basalis*

Vespa magnifica

Plate No. 4 *Vespa basalis* feeding on ripe bananas

orientalis were seen feeding on tree saps of *Albizzia* **lebbeck** after scratching the delicate branches with their strong mandibles. *V. auraria* was also observed feeding on the sap of tree *Thuja compacta*, nectar of *Callistemon lanceolatus*, ripe fruits of *Vitis vinifera* and *Litchi chinensis*, sweets, fish, meat and honey bees in good numbers. However, other species were also observed on most of these sources but comparatively in less number.

Table 1 List of different species of wasps collected in foot and mid hills of Himachal Pradesh during 1996-97

District	Location	Species
Kangra	Palampur	*Vespa auraria* (Smith)*
	Sarkari Sidhpur	*V. basalis* (Smith)**
		V. cincta (F.)**
		V. magnifica (Smith)*
		Vespa sp. (?)**
Una	Jhalera	*Vespa auraria* (Smith)*
	Khanpur	*V. basalis* (Smith)**
	Takka	*V. cincta* (F.)*
		V. orientalis (L.)*
		Vespa sp. (?)**

* Regular visitors
** Casual visitors

4.3 FORAGING BEHAVIOUR OF WASPS UNDER APIARY CONDITIONS

4.3.1 Diurnal trends of foraging *V. auraria* during different seasons in 1997

Diurnal trends of *V. auraria* visiting apiary during different seasons have been presented in Table 3. Data during summer (May-June) showed maximum population of *V. auraria*/bee hive/30 minutes at 0900-1000 hours (1.50) closely followed by 1300-1400 hours (1.42). Minimum population of *V. auraria* (0.92)

Table 2 Food sources of different wasps in mid and foot hills of Himachal Pradesh

Source	Scientific Name	*Vespa* species*					
		Va	Vb	Vc	Vm	Vo	Vsp
Flower Nectar							
Bottle brush	*Callistemon lanceolatus* DC	+	+	+	-	-	+
Litchi	*Litchi chinensis* Son.	+	-	+	-	-	-
Pajja	*Prunus puddum* Roxb.	+	+	+	-	-	+
Shisham	*Dalbergia sissoo* Roxb.	+	-	-	-	-	-
Tea	*Camellia sinensis* L.	+	-	-	-	-	-
Ripe fruits							
Apple	*Malus domestica* Borkh.	+	+	+	-	-	-
Banana	*Musa paradisiaca* L.	+	+	+	-	+	-
Grapes	*Vitis vinifera* Linn.	+	+	+	-	-	-
Mango	*Mangifera indica* Linn.	+	-	+	-	-	-
Peach	*Prunus persica* Batsch.	+	+	+	-	-	-
Litchi	*Litchi chinensis* Son.	+	+	+	-	-	-
Pomegranate	*Punica granatum* L.	+	-	+	-	+	-
Pipal	*Ficus religiosa* Linn.	+	+	-	-	-	-
Tree sap							
Morpankh	*Thuja compacta* L.	+	-	+	-	-	-
Siris	*Albizia lebbek* Benth.	+	-	+	-	+	-
Insects							
Housefly	*Musca domestica* Linn.	+	-	-	-	-	-
Honey bees	*Apis mellifera* L.	+	+	+	+	+	+
	Apis cerana Fabricius.	+	+	+	+	+	+
Other products							
Sweets		+	-	+	-	+	-
Gur		+	+	+	+	+	-
Fish		+	+	+	+	+	+
Meat		+	+	+	+	+	+

* Va - *Vespa auraria*; Vb - *Vespa basalis*; Vc - *Vespa cincta*; Vm - *Vespa magnifica*; Vo - *Vespa orientalis*; Vsp - *Vespa* sp.

was recorded at 1700-1800 hours (Fig. 3). However, population of foraging wasp did not differ statistically at different day hours. Correlation coefficient between the foraging population of wasp and temperature was found to be positive ($r = +0.42$) and with relative humidity, it was negative ($r = -0.32$). However, both

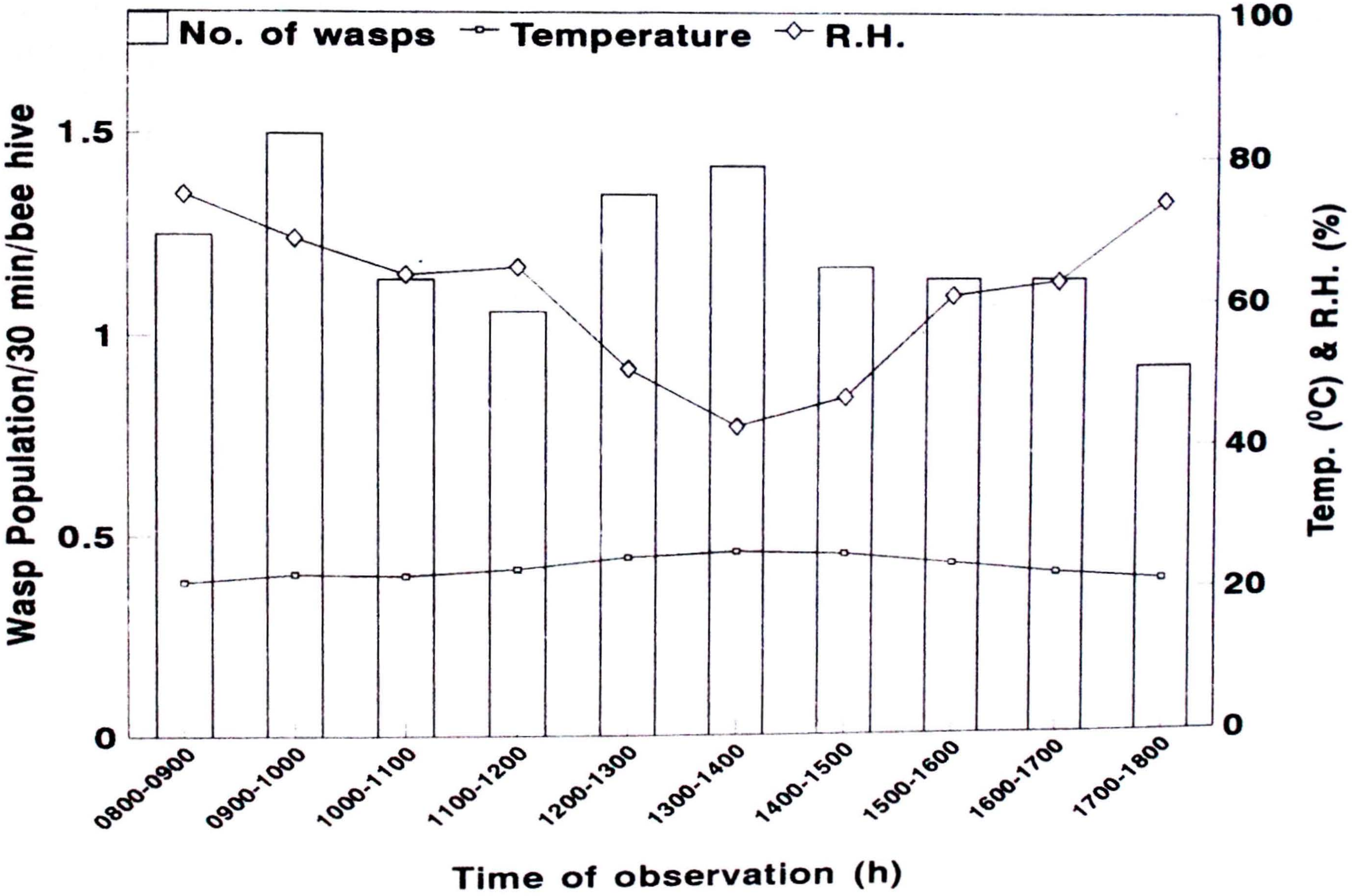


Fig.3 Diurnal trend of *Vespa auraria* in summer season during 1997

these coefficients were non-significant indicating that foraging population of wasp was not decisively influenced by either temperature or relative humidity.

Table 3 Diurnal trends of *Vespa auraria* in different seasons at Palampur during 1997

Day hours	Number of wasps visiting/30 min/hive		
	Season		
	Summer	Rainy	Autumn
0800-0900	1.25 (1.11)	1.94 (1.38)	3.13 (1.76)
0900-1000	1.50 (1.21)	2.05 (1.42)	3.78 (1.94)
1000-1100	1.14 (1.05)	2.15 (1.46)	4.24 (2.05)
1100-1200	1.06 (1.02)	1.87 (1.36)	3.90 (1.97)
1200-1300	1.35 (1.14)	1.90 (1.37)	3.91 (1.97)
1300-1400	1.42 (1.18)	1.56 (1.24)	3.92 (1.97)
1400-1500	1.17 (1.08)	1.68 (1.29)	3.51 (1.87)
1500-1600	1.14 (1.06)	1.84 (1.35)	3.78 (1.94)
1600-1700	1.14 (1.06)	1.46 (1.21)	3.63 (1.90)
1700-1800	0.92 (0.93)	1.49 (1.21)	3.04 (1.73)
C.D. (0.05)	(NS)	(NS)	(NS)
Coefficient of linear correlation (r)			
Mean Temperature	+ 0.43^{NS}	- 0.17^{NS}	+ 0.56^{NS}
Mean Relative Humidity	- 0.34^{NS}	+ 0.33^{NS}	- 0.61^{NS}

Figures in parentheses are $\sqrt{n}$ transformed values

During rainy season (July-August), maximum population of *V. auraria* (2.15/bee hive/30 minutes) was recorded at 1000-1100 hours, closely followed by 0900-1000 hours (2.05). Minimum number of wasps/bee hive/30 minutes were recorded at 1600-1700 hours (1.46). However, foraging population of wasp did not differ significantly at different day hours (Fig. 4). During this season wasp population was found to be negatively correlated with temperature (r = -0.17) and relative humidity was positively (r = +0.33) correlated. Both the coefficients, however, were non-significant revealing that wasp population was not significantly influenced by temperature and relative humidity.

From September to November in autumn, maximum population of *V. auraria* (4.24/bee hive/30 min) was recorded at 1000-1100 hours (Fig. 5) closely followed by 1100-1200 hours (3.90), 1200-1300 hours (3.91) and 1300-1400 hours (3.92). Minimum activity of *V. auraria* was observed at 1700-1800 hours (3.04). However, foraging population of wasp did not differ statistically at different day hours. Correlation coefficients between the temperature and relative humidity were non-significant. Although temperature (r = +0.58) was found to be positive, whereas, relative humidity was negatively correlated (r = -0.61). Coefficient of linear correlation indicated that both these weather parameters were of lesser significance.

4.3.2 Weekly trend of foraging *V. auraria* during different seasons in 1997

Weekly trend of *V. auraria* visiting *A. mellifera* colonies has been presented in Table 4. Maximum number of wasps per 30 minutes per hive were recorded on September, 22 (6.37), however, it was at par with wasp numbers recorded on September, 30 (5.32). Minimum population of wasps was recorded on May, 23 (1.47), however, it was at par with population on November, 29 (Fig. 6).

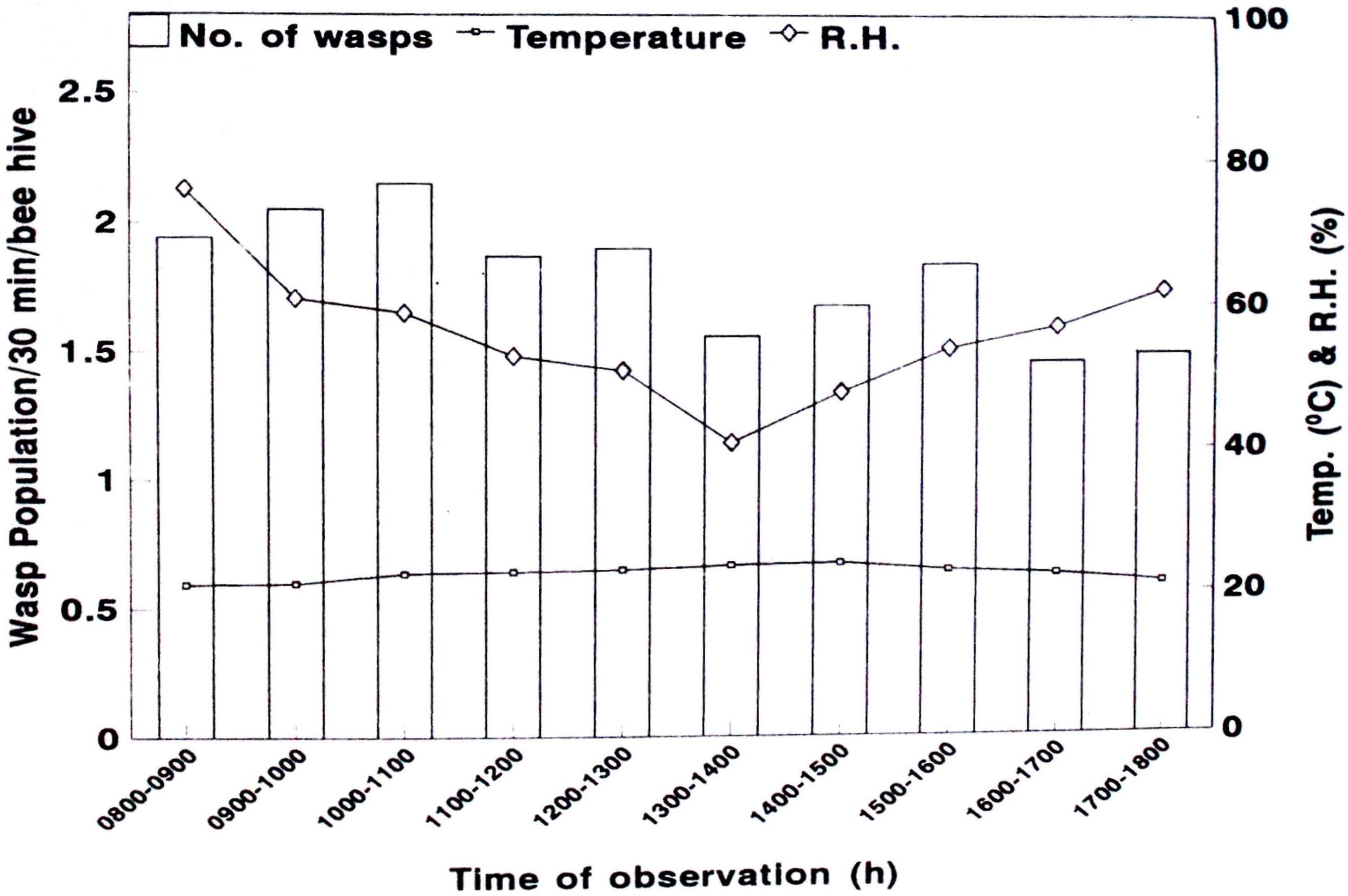


Fig.4 Diurnal trend of *Vespa auraria* in rainy season during 1997

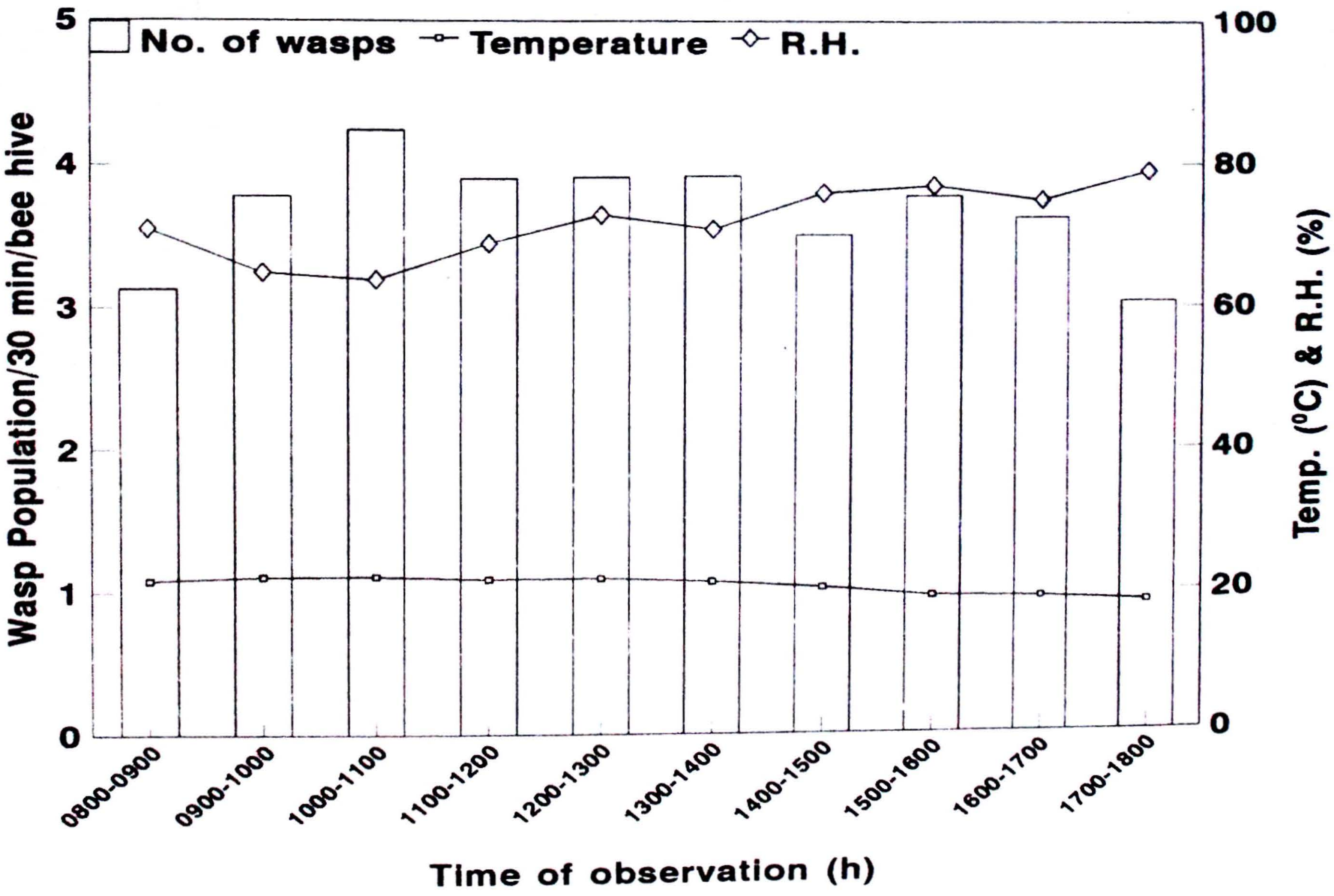


Fig.5 Diurnal trend of *Vespa auraria* in autumn season during 1997

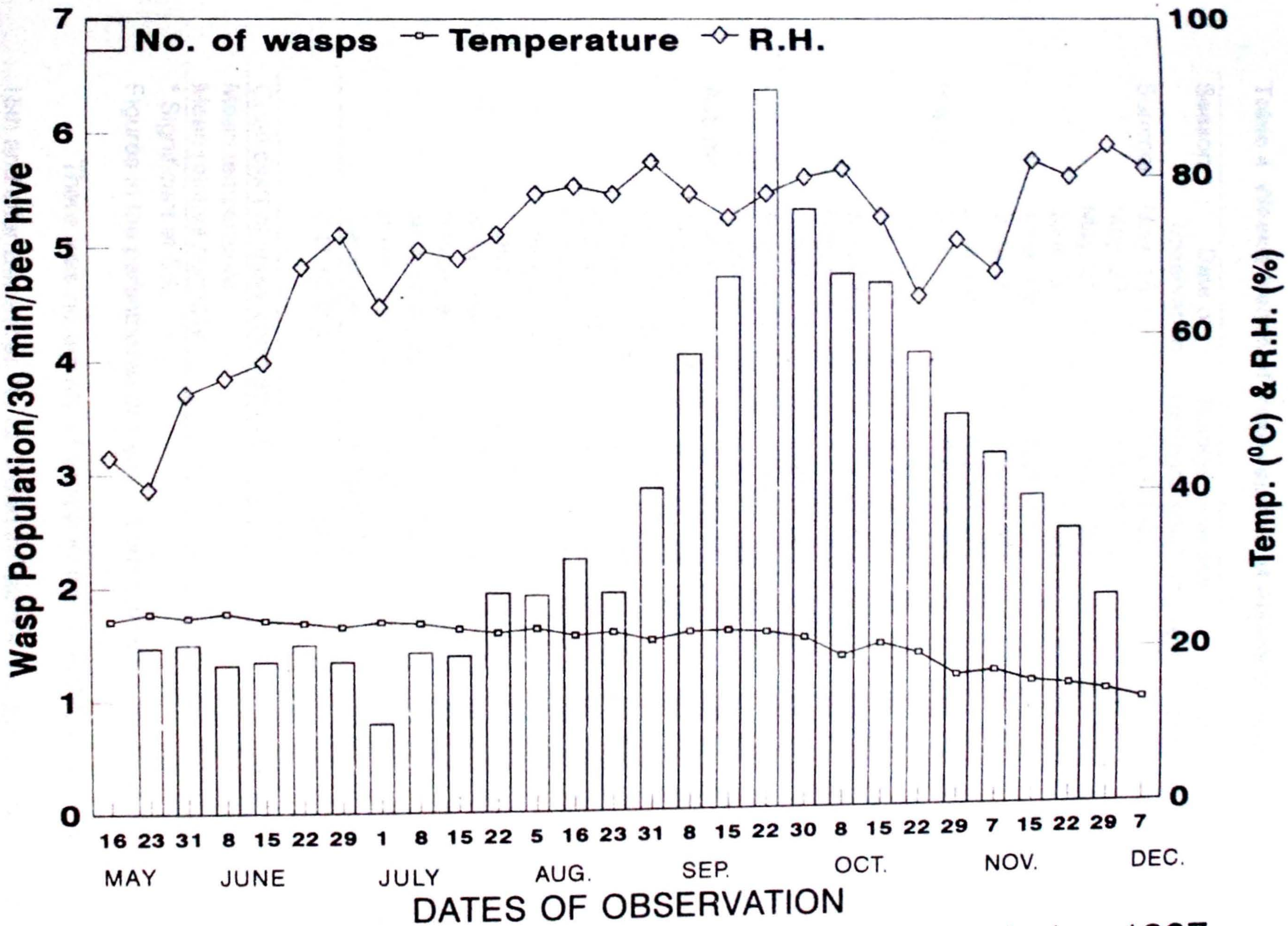


Fig.6 Weekly trends of *Vespa auraria* at Palampur during 1997

Table 4 Weekly trends of *Vespa auraria* at Palampur during 1997

Season	Date of observation	Number of wasps visiting/30min/hive	Mean temperature(°C)	Mean relative humidity (%)
Summer	May, 16	0.00 (1.00)	24.4	45
	May, 23	1.47 (1.57)	25.3	41
	May, 31	1.50 (1.58)	24.8	53
	June, 8	1.32 (1.52)	25.4	55
	June, 15	1.35 (1.53)	24.5	57
	June, 22	1.50 (1.57)	24.2	69
	June, 29	1.35 (1.53)	23.7	73
Rainy	July, 1	0.80 (1.34)	24.3	64
	July, 8	1.43 (1.55)	24.1	71
	July, 15	1.40 (1.55)	23.4	70
	July, 22	1.95 (1.71)	22.9	73
	August, 5	1.93 (1.71)	23.4	78
	August, 16	2.25 (1.80)	22.5	79
	August, 23	1.95 (1.72)	22.9	78
	August, 31	2.87 (1.96)	21.8	82
Autumn	September, 8	4.05 (2.24)	22.8	78
	September, 15	4.73 (2.38)	22.9	75
	September, 22	6.37 (2.71)	22.6	78
	September, 30	5.32 (2.53)	21.8	80
	October, 8	4.75 (2.39)	19.4	81
	October, 15	4.67 (2.38)	20.9	75
	October, 22	4.05 (2.24)	19.6	65
	October, 29	3.50 (2.12)	16.7	72
	November, 7	3.15 (2.03)	17.2	68
	November, 15	2.77 (1.94)	15.8	82
	November, 22	2.47 (1.86)	15.4	80
	November, 29	1.87 (1.69)	14.6	84
	December, 7	0.00 (1.00)	13.4	81
	C.D. (0.05)	(0.18)		

Coefficient of linear correlation (r)	'r' value
Mean temperature	-0.15^{NS}
Mean relative humidity	+0.44*

* Significant at 5%.

Figures in the parentheses are $\sqrt{n+1}$ transformed values

There was no activity of wasps in the *A. mellifera* colonies before May 16th and after December 7th as shown in Table 4. Foraging population of wasps in the apiary was at its peak on September, 22 , thereafter, it started declining with the decrease in temperature and with slight increase in humidity (Plate 5). Coefficient of correlation between foraging wasp population and temperature was negative and non-significant. However, wasp population was significantly and positively correlated with relative humidity.

4.4 PREDATION BEHAVIOUR OF WASPS

4.4.1 Time spent/catch (seconds)

Time spent by different *Vespa* spp. in capturing *A. mellifera* bees is given in Table 5. On an average *V. auraria* spent 84.19 seconds to catch a bee when hovering near the hive, whereas, *V. magnifica* took only 1.88 seconds per catch, indicating highly significant differences between the two species. Average time taken to capture a bee was significantly less at 1200-1300 hours (23.58 seconds) as compared to 0900-1000 hours (53.86 seconds) and 1500-1600 hours (51.66 seconds), irrespective of *Vespa* spp.

Interaction between *Vespa* spp. and the time was significant. Minimum time was taken by *V. magnifica* per catch at 0900-1000 hours (1.85 seconds) and maximum time was taken by *V. auraria* at 0900-1000 hours (105.87 seconds).

4.4.2 Successful predation of different *Vespa* spp.

Data on predation success of different *Vespa* spp. have been presented in Table 6. On an average predation success in *V. auraria* was 67.36 per cent, whereas, predation success in *V. magnifica* was recorded to be 99.92 per cent, which was significantly more as compared to *V. auraria*. As regard to the timings

Plate No. 5 A nest of *Vespa auraria* during September

and irrespective of the *Vespa* spp., maximum predation was recorded at 1500-1600 hours (84.52%) followed by 0900-1000 hours (83.95%) and 1200-1300 hours (82.45%).

Table 5 Time taken to capture *Apis mellifera* workers by *Vespa* spp. in *Apis mellifera* colonies at Palampur during October, 1996

Species	Time spent/catch (s)			
	Day hours*			Mean
	0900-1000	1200-1300	1500-1600	
Vespa auraria	105.87 (15-272)	45.27 (13-180)	101.43 (30-240)	84.19
Vespa magnifica	1.85 (1.7-2.0)	1.90 (1.7-2.0)	1.90 (1.6-2.2)	1.88
Mean	53.86	23.58	51.66	

C.D. (0.05)

Vespa species = 12.25
Time = 15.00
Vespa speciesxTime = 21.22

Figures in the parentheses are the range values
* Average of 30 observations

Interaction between the *Vespa* spp. and timings was significant. Minimum predation success (64.97%) was recorded at 1200-1300 hours in case of *V. auraria* and the maximum predation success (99.93%) was recorded in case of *V. magnifica* at 1200-1300 hours.

4.5 FORAGING BEHAVIOUR OF WASPS AND OTHER INSECT VISITORS UNDER FIELD CONDITIONS

4.5.1 Foraging behaviour of insect visitors

Toria : Table 7 showed the relative abundance of insect visitors to toria bloom. From the table it is evident that *A. cerana* was visiting *toria* bloom significantly in large numbers (13.99/m^2/15 min) followed by *A. mellifera* (11.39). Significantly lowest population was recorded of *A. dorsata* (4.83). As regard to the timings, significantly maximum insect visitors were recorded at 1500-1600 hours (10.96). The lowest number of insect visitors were recorded at 0900-1000 hours (7.99), however, it was at par with insect population at 1200-1300 hours (8.09).

Table 6 Successful predation of *Apis mellifera* workers by *Vespa* spp. in *Apis mellifera* colonies at Palampur during October, 1996

Species	Predation success (%)			
	Day hours*			Mean
	0900-1000	1200-1300	1500-1600	
Vespa auraria	67.99 (55.53)	64.97 (53.69)	69.13 (56.24)	67.36 (55.16)
Vespa magnifica	99.92 (88.38)	99.93 (88.45)	99.92 (88.31)	99.92 (88.38)
Mean	83.95 (71.95)	82.45 (71.07)	84.52 (72.27)	

C.D. (0.05)

Vespa species = (1.17)
Time = (NS)
Vespa speciesxTime = (2.03)

Figures in the parentheses are arc sine transformed values
* Average of 9 observations

The interaction between insect visitors and timings was significant. *A. cerana* population was recorded in large number (16.37) at 1500-1600 hours and the lowest population of *A. dorsata* was recorded at 0900-1000 hours (3.85).

Pajja : Data in Table 8 showed the number of insect visitors/15 min/m^2 bloom of Pajja. On pajja, activity of *A. mellifera* was highest (10.90), however, it was at par with *A. cerana* (9.78). *V. auraria* population was near to that of *A. cerana* and its population averaged to 9.12. *A. dorsata* was least abundant (2.53). Maximum population of insect visitors was recorded at 1500-1600 hours (8.31) which was at par with the insect visitors at 1200-1300 hours (8.23).

Table 7 Relative abundance of insect visitors to Toria (*Brassica campestris* var. '*toria*') bloom at Palampur during 1997

Insect species	Number of insect visitors/m²/15 minutes			
	Day hours			Mean
	0900-1000	1200-1300	1500-1600	
Apis mellifera	9.33 (3.07)	9.66 (3.10)	15.18 (3.89)	11.39 (3.36)
Apis cerana	14.18 (3.76)	11.43 (3.38)	16.37 (4.04)	13.99 (3.72)
Apis dorsata	3.85 (1.96)	4.80 (2.17)	5.85 (2.42)	4.83 (2.18)
*Drone flies**	6.85 (2.61)	7.47 (2.72)	8.90 (2.98)	7.74 (2.77)
Vespa auraria	5.75 (2.40)	7.09 (2.65)	8.52 (2.92)	7.12 (2.65)
Mean	7.99 (2.76)	8.09 (2.81)	10.96 (3.25)	
C.D. (0.05)	Insect visitors		= (0.19)	
	Time		= (0.15)	
	Insect visitorsxTime		= (0.35)	

Figures in parentheses are $\sqrt{n}$ transformed values
* *Eristalis tenax* and *Episyrphus balteatus*

The interaction between insect visitors and timings was significant indicating that *A. dorsata* was recorded in minimum number (1.75) at 1500-1600 hours and maximum population of *A. mellifera* was recorded at 1200-1300 hours (12.52).

Table 8 Relative abundance of insect visitors to Pajja (*Prunus puddum*) bloom at Palampur during 1997

Insect species	Number of insect visitors/m²/15 minutes			
	Day hours			Mean
	0900-1000	1200-1300	1500-1600	
Apis mellifera	7.90 (2.80)	12.52 (3.53)	12.28 (3.50)	10.90 (3.27)
Apis cerana	6.37 (2.51)	11.52 (3.38)	11.47 (3.38)	9.78 (3.09)
Apis dorsata	3.16 (1.73)	2.68 (1.63)	1.75 (1.30)	2.53 (1.55)
*Drone flies**	2.95 (1.70)	3.14 (1.75)	6.28 (2.49)	4.12 (1.98)
Vespa auraria	6.22 (2.49)	11.33 (3.36)	9.81 (3.11)	9.12 (2.98)
Mean	5.32 (2.24)	8.23 (2.73)	8.31 (2.75)	
C.D. (0.05)	Insect visitors		= (0.25)	
	Time		= (0.19)	
	Insect visitorsxTime		= (0.44)	

Figures in parentheses are $\sqrt{n}$ transformed values
* *Eristalis tenax* and *Episyrphus balteatus*

Bottle brush : Data in Table 9 showed the number of insect visitors/15 min./m² bloom of bottle brush. Activity of insect visitors on bottle brush bloom revealed that *A. cerana* populations was highest (9.56) which was at par with *A. mellifera* (9.34). Minimum population was recorded of *V. auraria* (6.62), however, its population was statistically at par with *A. dorsata* (6.92) and drone flies (6.81).

Table 9 Relative abundance of insect visitors to Bottle brush (*Callistemon lanceolatus*) bloom at Palampur during April, 1998

Insect species	Number of insect visitors/m^2/15 minutes			
	Day hours			Mean
	0900-1000	1200-1300	1500-1600	
Apis mellifera	6.66 (2.57)	11.14 (3.34)	10.23 (3.19)	9.34 (3.03)
Apis cerana	8.28 (2.87)	9.70 (3.11)	10.71 (3.27)	9.56 (3.08)
Apis dorsata	5.23 (2.28)	7.56 (2.74)	7.99 (2.82)	6.92 (2.61)
*Drone flies**	5.94 (2.44)	7.66 (2.76)	6.85 (2.54)	6.81 (2.58)
Vespa auraria	6.13 (2.46)	6.23 (2.49)	7.52 (2.74)	6.62 (2.56)
Mean	6.44 (2.52)	8.45 (2.88)	8.66 (2.91)	
C.D. (0.05)	Insect visitors		= (0.17)	
	Time		= (0.13)	
	Insect visitorsxTime		= (0.29)	

Figures in parentheses are $\sqrt{n}$ transformed values
* *Eristalis tenax* and *Episyrphus balteatus*

As regard to the timings, maximum population of insect visitors was there at 1500-1600 hours (8.66) closely followed at 1200-1300 hours (8.45). Over all population of insect visitors was significantly lowest at 0900-1000 hours (6.44).

Interaction between insect visitors and timings was significant. The minimum population of *A. dorsata* was recorded at 0900-1000 hours (5.23) and maximum population was of *A. mellifera* at 1200-1300 hours (11.14).

4.5.2 Predation bevahiour of wasps

Toria : Data in Table 10 indicate the number of insect visitors predated/15 min/m^2 bloom by *V. auraria*. On an average, 0.24 *A. mellifera* workers were predated as compared to 0.07 in case of *A. cerana*. No predation was recorded in case of *A. dorsata* and drone flies. Maximum predation (0.14) of insect visitors was recorded at 0900-1000 hours followed by 1200-1300 hours (0.05) and 1500-1600 hours (0.04), however, the differences in predation activities at different hours were non-significant.

The interaction between insect visitors and timings was found to be significant. Maximum predation occurred in case of *A. mellifera* (0.42) at 0900-1000 hours, but there was no predation of *A. dorsata* and drone flies.

Pajja : Data in Table 11 showed the number of insect visitors predated by *V. auraria* on pajja bloom/15 min./m^2. On an average significantly more *A. mellifera* workers (0.96) were predated as compared to *A. cerana* (0.37). However, *V. auraria* did not predate upon *A. dorsata* and drone flies at all. Maximum predation was recorded at 1200-1300 hours (0.38) followed by 0900-1000 hours (0.33) and 1500-1600 hours (0.29), however, there was not any significant difference in predation at different day hours.

Interaction between insect visitors and timings was found to be significant, as no predation of *A. dorsata* and drone flies was recorded whereas, in case of *A. mellifera* 1.14 bees were found to be predated at 1200-1300 hours.

Table 10 Insect visitors predated by *Vespa auraria* on Toria (*Brassica campestris* var. '*toria*') bloom at Palampur during 1997

Insect species	Number of insects predated/m²/15 minutes			
	Day hours			Mean
	0900-1000	1200-1300	1500-1600	
Apis mellifera	0.42 (1.18)	0.18 (1.08)	0.14 (1.06)	0.24 (1.10)
Apis cerana	0.14 (1.06)	0.04 (1.02)	0.04 (1.02)	0.07 (1.03)
Apis dorsata	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
*Drone flies**	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
Mean	0.14 (1.06)	0.05 (1.02)	0.04 (1.02)	
C.D. (0.05)	Insect visitors		= (0.06)	
	Time		= (NS)	
	Insect visitorsxTime		= (0.11)	

Figures in parentheses are $\sqrt{n+1}$ transformed values
* *Eristalis tenax* and *Episyrphus balteatus*

Bottle brush : Data in Table 12 showed the number of insect visitors predated by *V. auraria*/15 min./m^2 bloom. On an average 0.26 *A. mellifera* visitors were predated as compared to 0.05 in case of *A. cerana*. However, in case of *A. dorsata* and drone flies no predation was recorded. As regard to the timings, maximum predation of insect visitors were recorded at 0900-1000 hours (0.09), followed by 1200-1300 hours (0.08) and 1500-1600 hours (0.06), however, predation at different timings was found to be statistically non-significant.

Table 11 Insect visitors predated by *Vespa auraria* on Pajja (*Prunus puddum*) bloom at Palampur during 1997

Insect species	Number of insects predated/m^2/15 minutes			
	Day hours			Mean
	0900-1000	1200-1300	1500-1600	
Apis mellifera	0.90 (1.35)	1.14 (1.43)	0.86 (1.35)	0.96 (1.37)
Apis cerana	0.42 (1.19)	0.38 (1.17)	0.33 (1.15)	0.37 (1.17)
Apis dorsata	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
*Drone flies**	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
Mean	0.33 (1.13)	0.38 (1.15)	0.29 (1.12)	
C.D. (0.05)	Insect visitors		= (0.14)	
	Time		= (NS)	
	Insect visitorsxTime		= (0.24)	

Figures in parentheses are $\sqrt{n+1}$ transformed values
* *Eristalis tenax* and *Episyrphus balteatus*

Interaction between insect visitors and timings was significant. No predation was recorded in case of *A. dorsata* and drone flies but maximum predation was recorded in *A. mellifera* (0.33) at 0900-1000 hours.

4.6 FREQUENCY AND DURATION OF FORAGING TRIPS

Data in Table 13 showed the frequency and duration of foraging trips of *V. auraria* in the *A. mellifera* colonies during September-October, 1997. Highest number of foraging trips (43.5) were observed on September, 23 and it was at par on September,27 (35.1). The lowest number of foraging trips by *V. auraria* were made on October,13 (13.5) which were statistically at par on October,9 (16.8).

Table 12 Insect visitors predated by *Vespa auraria* on Bottle brush (*Callistemon lanceolatus*) bloom at Palampur during April, 1998

Insect species	Number of insects predated/m²/15 minutes			
	Day hours			Mean
	0900-1000	1200-1300	1500-1600	
Apis mellifera	0.33 (1.15)	0.23 (1.10)	0.23 (1.11)	0.26 (1.12)
Apis cerana	0.04 (1.02)	0.09 (1.04)	0.04 (1.02)	0.05 (1.02)
Apis dorsata	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
*Drone flies**	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
Mean	0.09 (1.04)	0.08 (1.03)	0.06 (1.03)	
C.D. (0.05)	Insect visitors		= (0.05)	
	Time		= (NS)	
	Insect visitorsxTime		= (0.09)	

Figures in parentheses are $\sqrt{n+1}$ transformed values
* *Eristalis tenax* and *Episyrphus balteatus*

Data in Table 13 also showed the time spent (in second) per foraging trip by *V. auraria*. The minimum time was spent on an average by *V. auraria* on September, 23 (502.50 seconds) which was statistically at par with time spent by *V. auraria* on all the dates except October, 13 *V. auraria* spent maximum time to complete its trip on October, 13 (927.40 seconds).

Table 13 Frequency and duration of foraging trips of *Vespa auraria* to *A. mellifera* colonies at Palampur during September-October, 1997

Date of observation	Number of trips/day	Time taken/trip (s)
September, 23	43.5 (6.44)	502.50
September, 27	35.1 (5.71)	508.50
October, 1	27.2 (4.98)	698.70
October, 5	22.7 (4.56)	796.60
October, 9	16.8 (3.88)	750.90
October, 13	13.5 (3.38)	927.40
C.D. (0.05)	(0.91)	296.39

Figures in parentheses are $\sqrt{n}$ transformed values

4.7 DEFENSIVE BEHAVIOUR

Defensive behaviour of *A. mellifera* and *A. cerana* was studied by recording observations on the number of wasps visiting honey bee colony (both *Apis* spp.), number of bees predated and the number of wasps left without honey bees.

4.7.1 Intensity of *V. auraria* in mixed apiary

Data in Table 14 showed the total number of *V. auraria* /10 min/bee hive. On an average, 4.53 wasps visited *A. cerana* colony as compared to 6.46 wasps in case of *A. mellifera* per colony. Data revealed that significantly more number of wasps were visiting *A. mellifera* as compared to *A. cerana* colony. Irrespective of *Apis* spp., the highest number of wasps were recorded on September, 14 which were, however, at par on all the observation days except on September, 20.

Table 14 Intensity of *Vespa auraria* in mixed apiary at Palampur during September, 1997

Species	Number of wasps* visiting/hive/10 minutes in September					Mean
	12	14	16	17	20	
Apis cerana	4.66 (2.15)	5.33 (2.30)	4.33 (2.08)	5.00 (2.23)	3.33 (1.82)	4.53 (2.12)
Apis mellifera	7.33 (2.70)	6.33 (2.51)	6.00 (2.45)	7.00 (2.64)	5.66 (2.37)	6.46 (2.53)
Mean	5.99 (2.42)	5.83 (2.40)	5.16 (2.26)	6.00 (2.43)	4.49 (2.09)	

C.D. (0.05)

Honey bees = (0.16)
Days = (0.25)
Honey beesxDays = (0.36)

Figures in parentheses are $\sqrt{n}$ transformed values
* Average of 15 observations

Table 15 Predation efficiency of *Vespa auraria* in mixed apiary at Palampur during September, 1997

Species	Number of bees* captured/hive/10 minutes in September					Mean
	12	14	16	17	20	
Apis cerana	0.33 (0.88)	1.00 (1.71)	0.66 (1.05)	0.33 (0.88)	0.00 (0.70)	0.46 (1.04)
Apis mellifera	5.33 (2.40)	4.66 (2.27)	4.33 (2.19)	5.33 (2.41)	4.33 (2.19)	4.79 (2.29)
Mean	2.83 (1.64)	2.83 (1.99)	2.49 (1.62)	2.83 (1.64)	2.16 (1.44)	

C.D. (0.05)

Honey bees = (0.20)
Days = (0.31)
Honey beesxDays = (0.45)

Figures in parentheses are $\sqrt{n+0.5}$ transformed values
* Average of 15 observations

Interaction between honey bees and days was found to be significant. Minimum number of wasps were visiting *A. cerana* colonies on September,20 (3.33) and maximum number of wasps were visiting *A. mellifera* colonies on September,12 (7.33).

4.7.2 Predation efficiency of *V. auraria* in mixed apiary

Data in Table 15 showed the number of honey bees predated/10 min/bee hive. On an average, 0.46 *A. cerana* bees were predated by *V. auraria* which was significantly lowest in number as compared to *A. mellifera* (4.79). As regard to days and irrespective of *Apis* spp., the highest number of bees were predated on September 12 , 14 , 17, and minimum predation was recorded on September,20. (2.16).

Interaction between honey bees and days was found to be significant. Maximum number of *A. mellifera* bees were predated on September,12 and on September,17 (5.33, each) and on September,20 , predation was nil in case of *A. cerana*.

4.7.3 *V. auraria* left without honey bees in mixed apiary

Data pertaining to *V. auraria* left without honey bees/10 min/bee hive during 1997 have been presented in Table 16. On an average, 4.06 *V. auraria* left the honey bee colony without any predation in case of *A. cerana* whereas only 1.66 *V. auraria* returned back without capturing honey bees in case of *A. mellifera* colony.

More number of *V. auraria* left without honey bees in case of *A. cerana* colonies as compared to *A. mellifera*. As regard to days and irrespective of *Apis* spp., the maximum number of *V. auraria* left without honey bees on September, 12 and 17 whereas minimum number of wasps were recorded on September, 20 leaving without honey bees.

Table 16 ***Vespa auraria*** **left without honey bees in mixed apiary at Palampur during September, 1997**

Species	Number of wasps failed to capture bees/hive/10 minutes in					
	September					Mean
	12	14	16	17	20	
Apis cerana	4.33 (2.08)	4.33 (2.08)	3.66 (1.91)	4.66 (2.15)	3.33 (1.82)	4.06 (2.01)
Apis mellifera	2.00 (1.41)	1.66 (1.28)	1.66 (1.28)	1.66 (1.28)	1.33 (1.14)	1.66 (1.27)
Mean	3.16 (1.74)	2.99 (1.68)	2.66 (1.59)	3.16 (1.71)	2.33 (1.48)	

C.D. (0.05)

Honey bees = (0.14)
Days = (0.22)
Honey beesxDays = (0.31)

Figures in parentheses are $\sqrt{n}$ transformed values

Interaction between the honey bees and days was found to be significant. Minimum number of *V. auraria* (1.33) were left without *A. mellifera* bees on September, 20 and maximum number of *V. auraria* left the *A. cerana* bees on September, 17 (4.66).

4.8 CONTROL

4.8.1 Relative attractiveness of different baits to *V. auraria*

Data in Table 17a showed the number of wasps/30 min attracted to different (meat/fish) baits. In case of meat baits, the maximum number (3.63) wasps were attracted to the jars having no insecticide followed by Baygon +

meat (1.82), carbaryl + meat (1.56) and Nuvan + meat (0.31) baits. Among the three poison baits, the maximum number of *V. auraria* were attracted to Baygon + meat bait, however, it was statistically at par with carbaryl + meat. Significantly lowest number of wasps were attracted to Nuvan + meat bait. As regard to the timings and irrespective of baits significantly highest number of *V. auraria* were attracted at 0900-1000 hours (3.99). Wasp attraction was recorded to be minimum at 1500-1600 hours (0.88), however, it was at par in between 1200-1500 hours.

Table 17a Relative efficacy of baits x insecticides against *Vespa auraria*

Day hour	Number of wasps attracted/Jar/30 minutes									
	Meat				Mean	Fish				Mean
	Carbaryl	Nuvan	Baygon	Control		Carbaryl	Nuvan	Baygon	Control	
0900-1000	3.44 (2.10)	1.11 (1.43)	5.44 (2.58)	5.99 (2.59)	3.99 (2.17)	4.77 (2.36)	0.99 (1.41)	2.32 (1.78)	8.44 (3.05)	4.13 (2.15)
1000-1100	2.33 (1.77)	0.22 (1.10)	3.10 (1.96)	4.99 (2.41)	2.66 (1.81)	1.88 (1.67)	0.33 (1.15)	2.55 (1.86)	7.55 (2.89)	3.07 (1.89)
1100-1200	1.77 (1.65)	0.33 (1.15)	1.77 (1.62)	3.22 (2.03)	1.77 (1.61)	1.55 (1.58)	0.66 (1.27)	1.21 (1.45)	5.55 (2.53)	2.24 (1.71)
1200-1300	1.21 (1.48)	0.22 (1.10)	0.99 (1.39)	3.33 (2.03)	1.44 (1.50)	0.66 (1.27)	0.77 (1.31)	0.33 (1.14)	4.33 (2.30)	1.52 (1.50)
1300-1400	0.88 (1.35)	0.11 (1.05)	0.77 (1.32)	2.66 (1.90)	1.11 (1.40)	1.22 (1.47)	0.55 (1.24)	0.44 (1.19)	4.10 (2.23)	1.58 (1.51)
1400-1500	0.88 (1.34)	0.11 (1.05)	0.22 (1.15)	2.66 (1.90)	0.96 (1.36)	1.77 (1.65)	0.22 (1.10)	0.11 (1.05)	5.11 (2.44)	1.80 (1.56)
1500-1600	0.44 (1.19)	0.11 (1.05)	0.44 (1.19)	2.55 (1.86)	0.88 (1.32)	0.66 (1.27)	0.22 (1.10)	0.44 (1.18)	4.55 (2.35)	1.47 (1.47)
Mean	1.56 (1.55)	0.31 (1.13)	1.82 (1.60)	3.63 (2.10)		1.78 (1.61)	0.53 (1.22)	1.06 (1.38)	5.66 (2.54)	

C.D (0.05)

Baits	= 0.14
Time	= 0.18
BaitsxTime	= NS

Figures in parentheses are $\sqrt{n+1}$ transformed values

In case of fish baits, the maximum attraction of wasps was observed in control (5.66), followed by carbaryl + fish (1.78), Baygon + fish (1.06) and Nuvan + fish (0.53) baits. Among the three poison baits significantly maximum number of *V. auraria* were attracted to carbaryl + fish bait closely followed by Baygon + fish bait. As regard to timings and irrespective of baits significantly highest number of *V. auraria* was attracted at 0900-1000 hours (4.13). Minimum number of wasps were attracted at 1500-1600 hours (1.47).

Table 17b Interaction effect of baits x insecticides on wasp attraction (pooled)

Preparation	Number of wasps/30 minutes				
	Baits				Mean
	Carbaryl	Nuvan	Baygon	Control	
Meat	1.56 (1.55)	0.31 (1.13)	1.82 (1.60)	3.63 (2.10)	1.83 (1.59)
Fish	1.78 (1.61)	0.53 (1.22)	1.06 (1.38)	5.66 (2.54)	2.25 (1.68)
Mean	1.67 (1.58)	0.84 (1.17)	1.44 (1.49)	4.64 (2.32)	2.04 (1.63)

C.D. (0.05)

Baits	= 0.14
Preparations	= NS
Baits x Preparations	= 0.20

Figures in parentheses are $\sqrt{n+1}$ transformed values

Data in Table 17b showed the interaction effect of insecticides and preparations (meat and fish). Carbaryl (1.67) was found more attractive to wasps followed by Baygon (1.44) and Nuvan (0.84). Carbaryl and baygon were at par with each other. Whereas, less number of wasps were attracted to Nuvan Preparations did not differ significantly, hence, indicated that fish and meat are equi-effective in attracting the wasps. Interaction between the preparations and insecticides was found significant. Maximum number of wasps were attracted to Baygon + meat bait (1.82) and minimum to Nuvan + meat bait (0.31).

4.8.2 Trapping

Plastic wet traps were kept in the *A. mellifea* apiary. The experiment was started on October, 2nd and the *V. auraria* trapped on different dates at three day interval were recorded (Table 18). On an average, maximum number of *V. auraria* were killed per trap on October, 11th (11.33), however, it was at par with trap catch recorded on October, 8th (10.33). Significantly less number of wasps were trapped on October, 29th (1.66). In total, 193 *V. auraria* were trapped/killed in 27 days from October, 2nd to 29th, 1997.

Table 18 *Vespa auraria* collected in plastic wet trap at Palampur during October, 1997

Date of observation	Number of wasps killed/trap/3 days
October, 5	9.33 (3.05)
October, 8	10.33 (3.21)
October, 11	11.33 (3.36)
October, 14	8.33 (2.88)
October, 17	8.33 (2.88)
October, 20	7.00 (2.63)
October, 23	5.00 (2.22)
October, 26	3.00 (1.71)
October, 29	1.66 (1.27)
C.D. (0.05)	(0.29)

Figures in parenthses are $\sqrt{n}$ transformed values

4.8.3 Bee Protectors

Data in Table 19 showed the number of *A. mellifera* predated by *V. auraria* in protected and unprotected colonies. On an average, 4.20 *A. mellifera* bees were predated/10 min/bee hive by *V. auraria* in colonies having Bee Protector-I which was statistically at par with predation rate in colonies having Bee Protector-II (4.23). However, in unprotected colonies comparatively more number of bees (4.83) were predated. Hence indicating the significance of Bee Protectors.

Table 19 Effect of Bee Protectors on predation rate of different *Vespa* spp. in *Apis mellifera* colonies

Protector type	Bees predated/hive by	
	V. auraria/10 min	*V. magnifica*/5 min
Bee Protector-I (6 mm gap)	4.20*	0.40*
Bee Protector-II (7 mm gap)	4.23*	0.47*
Control	4.83	161.53

* Treatments differ significantly from control in Student's t-test at P=0.05

The data on the number of *A. mellifera* predated by *V. magnific*. 5 min/bee hive revealed that in Bee Protector-I, 0.40 *A. mellifera* bees were predated which were statistically at par with the predation recorded in Bee Protector-II (0.47). In unprotected colonies, there was masive predation (161.53) of *A. mellifera* bees by *V. magnifica*. There was a reduction in the honey bee predation by *V. auraria* and *V. magnifica* from 12.4 to 13.0 per cent and 99.7 to 99.8 per cent, respectively.

DISCUSSION

Chapter - 5

DISCUSSION

The results of the investigation carried on "Foraging ecology and control of wasps associated with honey bees" are discussed in this chapter.

5.1 COLLECTION AND IDENTIFICATION OF WASPS

Six species of wasps viz., *V. auraria, V. basalis, V. cincta, V. magnifica, V. orientalis* and *Vespa* sp. were collected from different areas of Kangra and Una districts. However, Sharma and Raj (1988) have reported only five species from different places in Kangra and Dehra sub division. At Palampur, *V. orientalis* was not recorded during the period of study probably because this species is better adapted to hotter climate. According to Sharma and Raj (1988) *V. orientalis* occurs at lower elevations in Dehra sub-division of Kangra district which is comparatively a hot area like that of Una where this species has been recorded. Similarly, Brar *et al.* (1985) and Sihag (1992a; b) have reported this species from plains of Hissar and Punjab, respectively. However, at Una, *V. magnifica* was not recorded. This species has been reported to occur in colder regions/higher altitude (Mishra *et al.*, 1989; Matsuura and Yamane, 1990).

5.2 FOOD SOURCES

Twenty two food sources of different species of wasps were identified. Out of these, *V. auraria* was recorded on all the food sources, followed by *V. cincta*, *V. basalis*, *V. orientalis*, and *Vespa* sp. Minimum food sources are recorded in case of *V. magnifica*. The present observations find support of

Mishra *et al.* (1989) who have observed the wasps to feed on various fruit crops (apple, pear, plum, mango and peach). They further noted that *V. auraria* visited maximum number of fruit crops as compared to other wasps. Viswanath *et al.* (1970) and Sexana (1970) have also observed *V. tropica* (L.) (*cincta* F.) and *V. orientalis* feeding on half ripe and ripe grapes from different regions in India. Ripening apples and pears are also attacked by *V. magnifica* var. *mobilis* Sonam and *V. japonica* Sauss (Chang, 1968). In contrast, *V. magnifica* is not recorded feeding on any of the fruit sources during field and market surveys. However, it is recorded on 'gur', fish and meat in *A. mellifera* apiary. During the present investigations, the rest of wasps are not observed to feed on fruits only but also found feeding on flower nectar, tree sap, insects and manufactured sweets. The present studies are in accordance with Matsuura and Yamane (1990) who have recorded the wasps attract on the above mentioned food sources.

5.3 FORAGING BEHAVIOUR OF WASPS UNDER APIARY CONDITIONS

5.3.1 Diurnal and Weekly trends of *V. auraria*

Diurnal trends during summer (May-June), rainy (July-August) and autumn (September-December) showed that wasps were more in number/hive in the morning and noon hours and their number reduced in the evening hours. Almost similar findings have been reported by Brar *et al.* (1985). The possible reason for low population of wasps in summer is that wasps start their colonies in spring season and their population goes on increasing during rainy season and reached its peak during autumn season. The present investigations receive support of Sharma *et al.* (1985), Shah and Shah (1991), Sihag (1992a; b) and

Mishra (1995). Coefficient of linear correlation of wasp population with temperature and relative humidity during different seasons were non-significant, indicating that these factors did not contribute to the diurnal activity of the wasps. The present results are in accordance with Chang *et al.* (1993) who also reported non-significant correlation with weather factors however, other factors like light intensity and food requirement of the wasp are of importance which control the wasp activity in the apiary.

Weekly trend of foraging *V. auraria* during different seasons (summer, rainy and autumn) showed that wasps were more in number/hive/day during autumn compared to other seasons. Fecundated females start its nesting activity in the spring season when the temperature rises above 20 °C and sometimes during rainy season, it takes 3-4 months to build its nest and the colony goes on increasing in size and numbers till autumn which accounts for their low population during summer and rainy seasons. The present investigations are in accordance with Matsuura and Yamane (1990), Sharma *et al.* (1985), Shah and Shah (1991), and Mishra (1995). The population of *V. auraria* was at its peak during last week of September and thereafter started declining and no activity was recorded after Ist week of December in the apiary. Sharma and Raj (1988) also reported reduction in wasp activity during the second fortnight of November. Further decrease in population may be due to natural wasp mortality as these wasps have an annual life cycle and only newly mated queens are reported to survive during hibernation stage, which overwinter in soil, rotten wood of old stumps, logs, nooks and crevices. Similar findings were also reported by

Matsuura and Yamane (1990) and Mishra (1995). Wasp nest starts disintegrating in September and by the end of November, the process is faster due to fall in temperature, natural death of queens and lack of food sources (Matsuura and Yamane, 1990).

Weekly trend of wasp population indicate negative correlation with temperature. Similar findings have also been reported by Wafa (1956) and Sharma and Raj (1988) for *V. orientalis* and *V. auraria*, respectively. However, with relative humidity significant positive correlation has been observed which is in contrast with Sharma and Raj (1988).

5.3.2 Predation behaviour of wasp

V. auraria spent considerably more time (84.19 s, range, 13-272 s) per catch whereas *V. magnifica* took only 1.88 seconds (range, 1.6-2.2 s) to catch *A. mellifera*. Srivastava *et al.* (1995) reported 1.2-3.9 seconds by *V. magnifica* per catch of *A. mellifera* but they reported less time/catch (15.3-21.2 s) for *V. auraria*. The difference in the average time spent/catch of *A. mellifera* could be due to variation in bees activity at the hive entrance. Possible reason could be that incoming and outgoing bees were less in our case as *V. auraria* hovers around the hive and waits for incoming and outgoing bee, hence took more time to catch a bee. However, time spent/catch by *V. magnifica* in the present investigation is almost in accordance with findings of Srivastava *et al.* (1995).

Predation success ranged from 64.97 to 99.93 per cent in *V. auraria* and *V. magnifica*. Predation success was more in case of *V. magnifica*. It may be attributed to its predation behaviour at the hive entrance. *V. magnifica* during slaughter phase sits at the hive entrance and cut the approaching bees with its strong mandibles whereas *V. auraria* hovers at and around the hive and waits for the incoming and outgoing bees for its catch. Less predation of *A. mellifera* by *V. auraria* may be attributed to dodging tactics of bees as reported by Shah and Shah (1991). The present findings are also in accordance with Sakagami and Matsuura (1972) and Sharma *et al.* (1985) who have reported *V. magnifica* (= *mandarinia*) as most serious to beekeeping.

5.4 FORAGING BEHAVIOUR OF WASPS UNDER FIELD CONDITIONS

5.4.1 Foraging activity of insect visitors

V. auraria alongwith other insect visitors including honey bees was recorded to forage on different crops/plants viz., toria, pajja and bottle brush. On an average more number of *A. cerana* (9.34 to 13.99) bees were recorded on different crops/plants followed by *A. mellifera* (9.56-11.39), *V. auraria* (6.62-9.12), drone flies (4.12-7.14) and *A. dorsata* (2.53-6.92). All these insect visitors are recorded to collect nectar or pollen or both on these crops/plants during bloom as these are major nectar producing plants (Atwal and Sharma, 1986; Reddy and Gupta, 1987; Gupta and Kumar, 1993).

5.4.2 Predation activity of wasps

In addition to nectar collection, *V. auraria* has also been recorded to predate on honey bees while foraging on different crops/plants. On an average, more number of *A. mellifera* bees (0.24 to 0.96) predated by *V. auraria* than *A. cerana* (0.05-0.37) per m^2 bloom. Predation was maximum in case of *A. mellifera* on pajja. Sharma (1978) has also recorded honey bees predation on the flowers of Plectranthus, bottle brush and kachnar. Sihag (1992a; b) and Abrol (1994) reported the wasps to capture bees from flowers during May to December which support our findings. There exists little variations with respect to predation of wasps on different crops/plants as compared to apiary conditions because under field conditions, wasps have multichoice for food and have their own preference behaviour. Moreover, wasps forage mainly for nectar on crops and not for honey bees. There is more inter-specific competition which results in poor catch on flowers. The present investigation is in contrast with Sihag (1992b) who has also reported the predation of *A. dorsata* under field conditions. However, during the investigations, predation was not recorded in case of *A. dorsata*. This may be attributed to less number of *A. dorsata* bees foraging for nectar on toria, bottle brush and pajja as compared to domesticated bees.

5.5 FREQUENCY AND DURATION OF FORAGING TRIPS

The wasps started their activity at 0700 hours and on an average made 13.5-43.5 trips to *A. mellifera* colonies per day. Trips were maximum on the first day of observation (43.5) and these were reduced to 13.5 on the last date of observation. Reduction in the number of trips may be attributed to other nest duties to be performed by the wasps in between the foraging trips for the maintenance of their nests. Foraging trips reported in the present investigations are less as compared to the findings of Sharma *et al.* (1985). They have reported 150 trips per day. The frequency of trips is a direct function of distance between wasp nest and apiary site. More number of trips reported by Sharma *et al.* (1985) may be attributed to less distance of wasp nests to the apiary and food requirements.

Time spent/trip on an average was minimum (502.5 s) on the first day of observation which increased to 927.4 seconds after 20 days. More time spent/trip may be attributed to reduction in number of foraging trips/day by *V. auraria* to *A. mellifera* colonies and the reduction in trips might be linked with other food requirements of the wasp nest.

5.6 DEFENSIVE BEHAVIOUR

A. cerana was found more defensive against *V. auraria* as there was less bee predation (0.46/bee hive/10 min) as compared to *A. mellifera* (4.79/bee hive/ 10 min). Less predation in *A. cerana* may be attributed to hissing sounds produced in shimmering behaviour when the wasps approach the bee hives. Such observations have also been recorded by Ruttner (1988) who has reported that these hissing sounds force the wasps to abandon their attempts to attack this species. The present findings also find support from Matsuura and Sakagami (1973) who reported that *A. mellifera* is preferred more for attack when both the domesticated species are kept in an apiary. The findings of Shah and Shah (1991) are also in accordance with our studies who have reported less *A. cerana* predation by *V. velutina* compared to *A. mellifera* in the mixed apiary.

5.7 CONTROL

5.7.1 Baiting

On an average, carbaryl bait was found most effective in attracting wasps (1.67) followed by Baygon bait (1.44). Preparations (fish and meat) were found non-significant, hence showing that both fish and meat are equally effective and can be used for preparing poisoned baits. Sharma *et al.* (1979) have also reported toxic baits (trichlorfon-meat) as potential control measures against wasps. Later, Abrol (1994) found cypermethrin fish bait as the most attractive and effective in reducing wasps in the apiary. The present investigations also find support from Donovan (1992) and Akre and Mayer (1994) work who have also suggested the use of toxic baits prepared in meat and fish as most effective tool in the management of wasp population in the apiary.

5.7.2 Trapping

In total, 193 *V. auraria* were trapped during October in 27 days. Traps were found quite useful in attracting wasp to meat bait and killing them by means of drowning. Similar observations have also been recorded earlier during 1996 (Anonymous, 1997). Earlier, Sharma (1978) has tested traps baited with fish, meat, rotten apple and honey and he could trap 170 wasps during November. The present findings also find support from Davis *et al.* (1975) and Donovan (1992) who also suggested trapping as most effective means of reducing the wasp population in an apiary.

5.7.3 Bee Protectors

Bee Protectors were found most effective in protecting *A. mellifera* colonies against wasps attack especially from *V. magnifica*. However, these were also effective against *V. auraria* to some extent resulting in lesser predation of bees and disturbance to honey bee foraging activity at hive entrance. Further, these protectors would be of great help in case of weak colonies where wasps gain entry and cause heavy damage to the hives. Sharma *et al.* (1985) have also suggested the use of 'wooden box device' to protect the bees from the menace of *V. mandarinia*. The present findings also find support from the work of Thakur and Kashyap (1996) who have also suggested the use of Bee Protectors to discourage the activity of *V. magnifica* at hive entrance.

SUMMARY

Chapter - 6

SUMMARY

The present investigations on "Foraging ecology and control of wasps associated with honey bees" were undertaken mainly at Palampur. The salient findings are summarized hereunder.

Six species of wasps viz., *V. auraria, V. basalis, V. cincta, V. magnifica, V. orientalis* and *Vespa sp.* were recorded attacking honey bees in different areas of Kangra and Una districts during 1997. *V. auraria* was the most abundant species at both the places. *V. magnifica* was not present in Una but it caused greater loss under Palampur conditions. *V. orientalis* was not recorded damaging bee colonies at Palampur.

Wasps were observed feeding on 22 different food sources. *V. auraria* exhibited wide food range whereas *V. magnifica* had a narrow food range feeding only on insects, meat fish and gur.

Maximum number of wasp activity was seen between 0900-1400 hours and minimum activity of wasps was recorded between 0800-0900 and 1500-1800 hours. Both the weather parameters viz., temperature and relative humidity were not found affecting diurnal wasp population in apiary.

Weekly trends during different seasons revealed that wasp population fluctuated from 0.80 to 2.87 during summer and rainy seasons (May-August, 1997) at Palampur. Peak population of *V. auraria* occurred in last week of September (6.37) and their population reduced to zero during first week of December. Wasp population was non-significantly negatively correlated with temperature and significantly positively with relative humidity.

Among the two important predating wasps, *V. magnifica* spent less time per catch (1.88 s) as compared to *V. auraria* (84.19 s). Predation success was nearly cent per cent in case of *V. magnifica* but in case of *V. auraria* predation success was only 67.36 per cent in *A. mellifera* apiary.

Under field conditions, on an average more number of *A. mellifera* bees/m^2 bloom were predated by *V. auraria* than *A. cerana* on different crops/plants and maximum *A. mellifera* visitors were predated on pajja (*P. puddum*) flowers during autumn season.

V. auraria made, on an average, 43.5 trips/day in early age but with the increase in age of wasps there was considerable reduction in number of trips (13.5). In the beginning, time spent/foraging trip was minimum (502.50 s) which was increased to 927.40 seconds after 20 days.

A. cerana was found more defensive against *V. auraria* as less number of bees were predated (0.46) as compared to *A. mellifera* bees (4.79).

Both fish and meat baits prepared with carbaryl (0.05%) proved most effective followed by Baygon (0.05%). Plastic wet trap placed on the hive top was found effective in trapping *V. auraria* under apiary condition. During peak activity period, 193 *V. auraria* were trapped in 27 days.

Bee Protectors (6 and 7 mm) were highly effective in reducing the bees mortality against *V. magnifica* and there was little protection against *V. auraria*.

From the present investigation, it is concluded that wasps are causing lot of damage to honey bee colonies in Himachal Pradesh. Bee Protectors alongwith plastic wet traps and poison baits (carbaryl or Baygon in meat or fish @ 0.05%, each) can be a convenient and economical choice with the beekeepers in providing good control of wasps and the huge losses occurring every year in apiaries could be reduced.

LITERATURE CITED

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Abrol, D.P. 1994. Ecology, behaviour and management of social wasp *Vespa velutina* Smith (Hymenoptera : Vespidae) attacking honey bee colonies. Korean Journal of Apiculture 9 : 5-10.

Adlakha, R.L., Sharma, O.P. and Dhaliwal, H.S. 1974. Wasps as serious enemies of honey bees. Farmer and Parliament 13 : 25.

Akre, R.D. and Mayer, D.F. 1994. Bees and Vespine Wasps. Bee World 75 : 29-37.

Anonymous, 1933. The hornet and methods for combating it. Veterinary Sery. Ser. Department of Agriculture 7 : 6.

Anonymous, 1950. The Wasp Menace. Indian Bee Journal 12 : 69-70.

Anonymous, 1997. Annual Progress Report, 1996-97 Department of Entomology, HPKV, Palampur, H.P.

Atakishiev, T.A. 1971. Hive cohabitants in Azerbaidzhan Uchenva Zaniski Kazanakago Institute 109 : 261-265.

Atwal, A.S. and Sharma, O.P. 1986. Beekeeping in Punjab. Bilori Printing press, Ludhiana 71p.

Brar, H.S., Gatoria, G.S., Jhajj, H.S. and Chahal, B.S. 1985. Seasonal infestation of *Galleria mellonella* and population of *Vespa orientalis* in *Apis mellifera* apiaries in Punjab. Indian Journal of Ecology 12 : 109-112.

Caron, D.M. and Schaefer, P.W. 1986. Social Wasps as bee pests. American Bee Journal : 269-271.

Chang, S.C. 1968. The wasps destructive to pears and apple fruits in Taiwan. Plant Protection Bulletin, Taiwan 10 : 49-51.

Chang, Y.D., Lee, M.Y., Yim, Y.H. and Youn, Y.N. 1993. Species and visiting pattern of wasps (Hymenoptera : Vespoidea) in an apiary. Korean Journal of Apiculture 8 : 22-28.

Christie, G.D. 1994. Evaluation of non-toxic bait traps for yellow jacket control. Pest Control 62 : 38-39.

Clapperton, B.K., Alspach, P.A., Moller, H. and Matheson, A.G. 1989. The impact of common and German Wasps (Hymenoptera : Vespidae) on the New Zealand beekeeping industry. New Zealand Journal of Zoology 16 : 325-332.

Coelho, J.R. and Hoagland, J. 1995. Load lifting capacities of three species of yellow jackets (*Vespula*) foraging on honey bee corpses. Functional Ecology 9 : 171-174.

Collins, A.M. and Kobasek, K.J. 1982. Field test of honey bee (Hymenoptera : Apidae) colony defensive behaviour. Annals of the Entomological Society of America 75 : 383-387.

Collins, A.M. and Rinderer, T.E. 1986. The defensive behaviour of the Africanized bee. American Bee Journal : 623-627.

Collins, A.M. and Rinderer, T.E. 1991. Genetics of defensive behaviour I. The "African" Honey bee. Oxford. UK 309-328.

Dave, M.L. 1943. Wasps. Indian Bee Journal 5 : 127-131.

Davis, H.G., Johansen, C.A. and Eves, J.D. 1975. The attractiveness to bees of synthetic wasp attractants. Journal of Apicultural Research 14 : 101-104.

Delmotte, C. and Mathot, P. 1983. Tests of differently coloured traps for catching wasps (Hymenoptera : Vespidae). Bulletin and Annales de la societe Royale Belge d Entomologie 119 : 99-110.

Donovan, B.J. 1985. Wasp control. Weta 8 : 41-44.

Donovan, B.J. 1992. Problems caused by immigrant German and Common wasps in New Zealand, and attempts at biological control. Bee World 3 : 131-147.

Edwards, R. 1977. Trapping wasps (*Vespula* species) and (*Apis mellifera*) at a sweet factory. In Proceedings of the Eighth International Congress of the International Union for the Study of Social Insects. Wageningen, The Netherlands, September 5-10, 1977 : 300.

Feytaud, J. 1927. Les guepea. Bulletin of society of Zoologia Agriculture XXVI : 129-137, 145-153.

Ghosh, C.C. 1924. Reports by Entomologists, Mandaley for years ending 30th June 1922 and 1923 pp. 1-14 and 1-19. Rangoon.

Gupta, J.K. and Kumar, J. 1993. Bottle brush, *Callistemon lanceolatus* DC (Myrtaceae) nectar : amount , type of nectar sugars and honey bee foraging. Apidologie 24 : 564-568.

Ibrahim, M.M and Mazeed, M.M. 1967. Studies on the oriental hornets, *Vespa orientalis* F. Agricultural Research Review Cairo 45 : 163-180.

Ishay, J, Bytinski-salz, H. and Shulov, A. 1967. Contribution to the bionomics of the oriental hornet (*Vespa orientalis* Feb.) Israel Journal of Entomology 2 : 45-106.

Kshirsagar, K.K 1971. A wasp trap to control predatory wasps in the apiary. Indian Bee Journal 33 : 55-57.

Kshirsagar, K.K. and Mahindre, D.B. 1975. Some notes on bee predator wasps in India. Indian Bee Journal 31 : 4-9.

Mac Donald, J.F., Akre, R.D. and Hill, W.B. 1973. Attraction of yellowjackets (*Vespula species*) to heptyl butyrate in Washington State (Hymenoptera : Vespidae). Environmental Entomology 2 : 375-379.

Mac Govern, T.P., Davis, H.G., Beroza, M., Ingangi, J.C. and Eddy, G.W. 1970. Esters highly attractive to *Vespula* spp. Journal of Economic Entomology 63 : 1534-1536.

Macrovitch, S. 1952. Observation on insect pests in Israel. FAO Plant Protection Bulletin 1 : 25-26.

Maniog, A. and Patetta, A. 1987. Wasps. Apicoltore Moderno 78 : 245-253.

Matsuura, M. 1988. Ecological study on vespine wasps (Hymenoptera : Vespidae) attacking honey bee colonies. I. Seasonal changes in the frequency of visits to apiaries by vespine wasps and damaged inflicted, especially in the absence of artificial protection. Applied Entomology and Zoology 23 : 428-440.

Matsuura, M. and Sakagami, S.F. 1973. A bionomics sketch of the giant hornet, *Vespa mandarinia* a serious pest for Japanese Apiculture Hokkaido University Series VI Zoology, Journal of Food Science : 125-162.

Matsuura, M. and Yamane, S. 1990. Biology of the Vespine Wasps. Springer Verlag Berlin Heidelberg 323 p.

Mayer, D.F., Akre, R.D., Antonelli, A.L. and Burgett, D.M. 1987. Protecting honey bees from yellow jackets. American Bee Journal : 693

Mellor, J.E.M. 1928. The oriental hornet (*Vespa orientalis*) Fab. Leaflets Plant Proct. Sect. Ministry of Agriculture Egypt No. 1, 6 pp.

Mellor, J.E.M. 1929. Beekeeping in Palestine and Egypt compared. Bulletin Technique Science Sery. Ministry of Agriculture Egypt No. 82, 17 pp.

Mishra, R.C. 1995. Honey Bees and Their Management in India. I.C.A.R. Publication, New Delhi : 168 p.

Mishra, R.C., Kumar, J. and Gupta, J.K. 1989. A new approach to the control of predatory wasps (*Vespa spp.*) of the honey bee (*Apis mellifera* L.). Journal of Apicultural Research 28 : 126-130.

Mutto, R.N. 1949. Enemies of Honeybees in India. Bhupen Apiaries piot. Ser. No. 2.

Muzaffer, N. and Ahmed, R. 1986. Studies on hornets attacking honey bees in Pakistan. Pakistan Journal of Agricultural Research 7 : 59-63.

Ono, M., Igarashi, T., Ohno, E. and Sasaki, M. 1995. Unusual thermal defense by a honey bee against mass attack by hornets. Nature 377 : 334-336.

Patt, J.M, Hamilton, G.C. and Lashomb, J.H. 1997. Foraging sources of parasitoid wasps on flowers : interplay of insect morphology, floral architecture and searching behaviour. Entomologia Experimentalis et Applicata 83 : 21-30.

Patyal, S.S. 1995. Personal Communication, B.K.D.O. Kangra (H.P.).

Rajgopal, D., Hanumantha Swamy, B.C. and Kenchareddi, R.N. 1997. Predatory wasp menace on honey bees and its management. National Conference on Apiculture and First Karnataka Honey Festival, Bangalore. Jan 6-8.

Raw, G.R. 1954. 'Science and practice enemies of bees'. Bee World 35 : 159-160.

Reddy, M.C.M. and Gupta, J.K. 1987. Wild cherry, *Prunus paddum* Roxb., A honey plant. In social Forestry for Rural Development (ed. P.K. Khosla and R.K. Kohli), Indian Society of Tree Scientists : 207-214 pp.

Rogers, C.J. and Lauret, T.H. 1968. A standard yellow jacket trap for population sampling and control evaluation. Journal of Economic Entomology 61 : 1739-1740.

Ruttner, F. 1988. Biography and Taxonomy of Honey Bee. Springer-Verlag, Berlin.

Sakagami, S.E. and Matsuura, M. 1972. Aspectos da biologia da *Vespa mandarinia* importante praga da apicultra no japao. Homenagem a Warwick E. Kerr : oferecida pelos seua exalunos por ecasiao de seu 50° aniversario Rio claro Brazil Faculadade de Filosofia clencias o letras : 251-258.

Saxena, D.K. 1970. Honey bees and wasps as pests of grape. Journal of the Bombay Natural History Society 67 : 121-122.

Shah, F.A. and Shah, T.A. 1991. *Vespa* velutina, A serious pest of Honey bees in Kashmir. Bee World 72 : 161-164.

Sharma, O.P. and Raj, D. 1988. Ecological studies on predatory wasps attacking Italian honey bee *Apis mellifera* L. in Kangra Shivaliks. Indian Journal of Ecology 15 : 168-171.

Sharma, O.P., Thakur, A.K. and Garg, R. 1985. Control of wasps attacking bee colonies. Indian Bee Journal 47 : 27-29.

Sharma, P.L. 1978. Incidence, extent of damage and control of predatory wasps in apiaries. M.Sc. Thesis. Himachal Pradesh University, Agricultural Complex, College of Agriculture, Solan.

Sharma, P.L., Dogra, G.S. and Mishra, R.C. 1979. Evaluation of methods of control of predatory wasps, *Vespa spp.* in apiaries. Indian bee Journal 41 : 10-16.

Shinde, S.G. and Phadke, R.P. 1995. Beekeeping in India History, Present Status and Future. Indian Bee Journal 57 : 31-37.

Sihag, R.C. 1992a. The yellow banded brown wasp *Vespa orientalis* L.I.A predator and colony robber of honey bee (*Apis mellifera* L.) in Haryana (India). Korean Journal of Apiculture 7 : 32-34.

Sihag, R.C. 1992b. The yellow banded wasp *Vespa orientalis* L. 2. Population density, bee capture efficiency and predation rate on honey bee *Apis mellifera* L. Korean Journal of Apiculture 7 : 35-38.

Singh, G. 1972. Defensive behaviour of *Apis indica* F. (Hill Strain) against predatory hornets in Kashmir. Indian Bee Journal 34 : 65-69.

Singh, S. 1962. Beekeeping in India. I.C.A.R. Publication, New Delhi.

Spurr, E.B. 1991. Reduction of wasp (Hymenoptera : Vespidae) populations by poison-baiting; experimental use of sodium monofluoroacetate (1080) in canned sardine. New Zealand journal of Zoology 18 : 215-222.

Spurr, E.B. and Elliott, G. 1996. User trials with finitron wasp bait. New Zealand Beekeeper 3 : 18-20.

Srivastava, S., Kumar, A., Kashyap, N.P., Chandel, Y.S. and Raj, D. 1995., A new device to protect honey bees from the predatory wasps at the entrance of *Apis mellifera* L. colonies. Uttar Pradesh Journal of Zoology 15 : 165-174.

Subbiah, M.S. and Mahadevan, V. 1957. *Vespa cincta* Fab. A predator of honey bees and its control. Indian Journal of Veterinary Science 27 : 153-154.

Taber, S. 1987. Bee behaviour. American Bee Journal : 257-260.

Taylor, F. 1939. Beekeeping for the beginners. Union of South Africa Department of Agriculture. Bulletin No. 199.

Thakur, S.S. and Kashyap, N.P. 1996. Wasp control by lure trap in apiary. Insect Environment 2 : 6-7.

Tokuda, Y. 1928. The Honey Bee. Vol. 1 (In Japanese) Maruzen and Company, Tokyo 379 pp.

Venkata Rau, P.N. 1945. Enemies of Honey Bees. Indian Bee Journal 7 : 85-87.

Viswanath, B.N., Nalawadi, U.G. and Kulkarni, K.A. 1970. The yellow banded wasp, *Vespa cincta* Fabr. as a pest of grapes. Agricultural Research Journal of Kerala 8 : 53.

Wafa, A.K. 1956. Ecological investigations on the activity of the oriental hornet, *Vespa orientalis* with special reference to its damage to colonies of honey bees. Cairo University, Faculty of Agriculture Bulletin Number 103, pp. 1-35.

Wafa, A.K. EL-Horolosay, F.M. and Charkawi, S.G. 1969. Control work of *Vespa orentalis* F. Bulletin of Entomologia Society Egypt Economi Survey 3 : 9-16.

Wafa, A.K., El-Horolosay, F.M. and Charkawi, S.G. 1968. Studies on *Vespa orientalis* F. Bulletin of Society Entomologia Egypt 2 : 9-27.

Wang, J.D., Zhang, W.H., Wang, Y.M. and Lin, H.R. 1985. Biological study on several kinds of wasps preyed upon honey bees and their control. Journal of Fujian Agricultural College Fujian Nongxueyuan Xuebo 14 : 59-63.