STUDIES ON THE PREDATORY WASPS OF HONEYBEES AND THEIR CONTROL

THESIS

BY

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CERTIFICATE-I

This is to certify that the thesis entitled "**Studies on the predatory wasps of honeybees and their control**", submitted in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE** in **ENTOMOLOGY AND APICULTURE** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, is a record of bonafide research work carried out by **Mr Ajay Kumar** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

The assistance and help received by him during the course of investigations have been fully acknowledged.

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CHAPTER 1

INTRODUCTION

Honeybees are attacked by a variety of predators, parasites and diseases. Among these, the social hymenopterans of the genus *Vespa,* commonly called hornets, are recognized as important predators as they pose great threat to honey bee colonies. They are predatory in nature and catch bees from blossoms and at the hive entrance. They not only kill and eat bees but also rob brood and honey stores of the bee colonies. Persistent attack disorganizes and demoralizes the bee colony by eliminating the guard and field bees forcing them to stop foraging activity. Ultimately the colony becomes weak and sometimes may lead to absconding leaving behind lot of honey and brood (Sharma *et al.,* 1979).

The origin centre of *Vespa* species is probably Southern China to Eastern Himalayas (Van-der-Vecht, 1957). The wasps need proteins and carbohydrates for survival. Proteins are obtained mainly from insects for feeding the brood, whereas carbohydrates are taken in the form of nectar, fruit juices etc. which provide energy to adults and larvae. It is estimated that in the course of its life, a single female wasp uses 60-80 bees as food while the males live entirely on nectar (Hirschfelder and Landesanstat, 1952).

In temperate region, colonies of wasps are annual with fertilized queens overwintering in diapausing stage, whereas in the tropics, the perpetuation is cyclic and all stages of development are found in the colony round the year (Van-der-Vecht, 1957) . In India, the wasps become extremely active during the monsoon and their activities continue till the advent of winter season causing great damage to

beekeeping industry. The abundance of wasps during certain years has been related directly to rainfall and temperature in spring (Long *et al.*, 1979; Akre and Reed, 1981).

There are five species of predatory wasps viz. *Vespa magnifica* Smith *(=Vespa mandarina* Smith*), Vespa cincta* Vecht.*(=Vespa tropica* Vecht.*)* , *Vespa auraria* Smith *(=Vespa velutina* Smith*), Vespa basalis* Smith and *Vespa orientalis* L., which attack the colonies of *Apis mellifera* L. and *Apis cerana* Fabr. in Himachal Pradesh (Sharma and Raj, 1988). The damage caused to *A. cerana* colonies is, however, comparatively less than to *A. mellifera* colonies. This is because of the fact that *A. mellifera* bees, in a bid to defend themselves, fly out of the hive and attack the wasp, whereas *A. cerana* remains near the hive entrance and resorts to shimmering movements in order to frighten the wasps and are attacked to a lesser extent. Nearly 150-350 workers of *V. auraria* visit the apiary in Kangra during the period of maximum attack and a single wasp could lift away upto 150 worker bees in a day, whereas a single wasp of *V. magnifica* could devour about 200 *A. mellifera* bees in 5-10 minutes (Sharma *et al.*, 1985).

Control of predatory wasps is beyond the means of an average beekeeper. In 1948 , the Department of Agriculture, New Zealand was forced to undertake nationwide anti wasp campaign to protect the bee industry. Because of the seriousness of wasp problem, several methods have been tried to control them in different parts of the world. Among them, fumigation with calcium cyanide after plugging the entrance hole (Robin and Dupres,1945; Subbiah and Mahadevan,1957; Singh,1962) and destruction of wasp nests by burning (Bhutani,1950; Singh,1962; Sharma *et al.*, 1979) have been tried. Different types of traps have been devised (Ibharim and Mazeed, 1967; Wafa *et al.*, 1968; Kshirsagar, 1971; Reierson and Wagner, 1975; Longo, 1980) and many organic chemicals have been used as lures (Davis *et al.*, 1968; Wagner and Reierson, 1969; Mc Govern *et al.*, 1970) with varying degrees of effectiveness. A queen guard or queen gate of 12.7x5.1 cm (Dave, 1943) and elimination of the alighting board (Subbiah and Mahadevan,1957)

is reported to be useful in reducing the attack. Baiting the predatory wasps with fish and meat (Wagner and Reierson, 1969; Sharma *et al.,* 1979) and fruits (Mishra *et al.*, 1989) were also tried. The *capsule cup* technique developed by Mishra *et al.*, (1989) was reported to show good results for the control of *V. cincta.*

In Himachal Pradesh, presently beekeeping with *A. mellifera* is facing a big threat from predatory wasps mainly during August to November. Large number of bee colonies are destroyed by the attack of *V. auraria* and *V. magnifica*. The present studies were, therefore, undertaken with the following objectives:

1. To study the incidence of predatory wasps in relation to temperature and rainfall.
2. To evaluate different methods of controlling the wasps.

CHAPTER 2

REVIEW OF LITERATURE

Keeping in view the seriousness of the problem posed by the wasps to the bee industry, attempt has been made in this chapter to review the literature in context of the incidence, extent of damage to bees and control of the wasps.

There are about 15,000 species of stinging wasps belonging to Hymenoptera: Vespidae (Vierick,1916; Hurd, 1955). The vespidae includes a number of species which have extremely diverse habits. Behaviour varies from presocial to eusocial in those species that are known and for many others there is no such information. Colonies in temperate zones are annual with fertilised queens overwintering in diapausing stage, whereas in the tropics they are cyclic, with colonies in all stages of development throughout the year (Van-der-Vecht,1957).

Wasps are powerful and agile insectivorous social organisms. Their prey include butterflies, moths, caterpillars, wasps, bees and flies. Hornets are the largest of the social wasps and as such are physically capable of preying on honey bees with ease. Some hornet species are quite easily aroused to attack and sting in great numbers. This trait of the *Vespa* spp combined with the predation on honey bees and the damage they inflict on ripening fruits, make hornets a serious pest to man.

Feytaud (1927) reported seven species of *Vespa* in France out of which *V. germanica, V. carbro* and *V. vulgaris* were more injurious in apiaries, orchards and vineyards. According to Ishay *et al.* (1967), *V. orientalis* is a primary pest of honeybees and various summer fruits from Southern and Eastern parts of Mediterranean basin, South-east and Central Asia, Egypt, Arabian peninsula, Sahara, Ethopia and Malagash. According to Spradbery (1973) also *V. orientalis* in the

middle east is a pest to be feared for their ravages of fruit crops and honeybee colonies making horticulture and agriculture at times difficult and virtually impossible. Mellor (1928,1929) concluded that *V. orientalis* is a serious pest in apiaries and Wafa *et al.*, (1969) stated its economic importance in Egypt. It has also been reported as a serious pest and for some years it plagued the bee industry, especially in Fayoun region of Egypt (Anon.,1933), in Palestine (Macrovitch, 1952) and in Israel (Ibrahim and Mazeed,1967).

In South Africa, two pirate wasps *Palarus latifrons* and *Philanthus diadema* have been reported to attack honeybees (Taylor,1939). In India, the yellow wasps *Polistis habraeus* and bee hunter wasp, *Philanthus ramakrishnae* have been reported to cause trouble in apiaries of hills and plain areas of Punjab (Singh,1962). Muzaffer and Ahmed (1986) reported that *V. basalis, V. orientalis orientalis, V. tropica haematodes, V. velutina pruthii* and *V. germanica* preyed upon *A. mellifera* and *A. cerana* in Pakistan. Out of these, *V. velutina pruthii* and *V. basalis* were the most destructive predators which caused heavy losses of adult bees and their brood. According to them, *A. mellifera* was more susceptible than *A. cerana*.

Wang *et al.*, (1985) investigated the biology and behaviour of different *Vespa* species such as *V. mandarina, V. bicolor, V. basalis, V. tropica haematodes, V. ducalis* and *V. affinis*, as predators of honeybees in Fujian China. Clapperton *et al.*, (1989) concluded from the questioneers sent to 600 beekeepers in New Zealand that the wasp, *V. vulgaris* was a nuisance which seriously affected 8.13 to 9.39% of hives during 1985 to 1987. Beekeepers in South Island faced greater hive damage levels than beekeepers elsewhere in the country by its attack.

Atakishiev (1971) has recorded the severe attack and damage to the bee colonies by *V. orientalis* alongwith *V. vulgaris* and *V. crabro* in spring and autumn and mountain areas were especially susceptible in USSR. Okada (1956) collected four species of hornets viz., *V. mandarina, V. xanthoptera, V. crabroformis* and *V. lewis* from the apiary of Tamagama University in Japan. *V. mandarina* was reported

to pose a serious threat to the bee industry than *V. mongolica* (Tokuda, 1928; Sakagami and Matsurra,1972).

According to Dave (1943) wasps are serious pest both in hills and plains of India. He reported four species out of which the big brown wasp (*V. magnifica*) and smaller yellow wasp (*V. auraria*) are more destructive to the bee colonies. Venkata Rau (1945) also reported yellow wasps as real menace to bee industry in India. Mutto (1949) reported that social wasps are major predators of honeybees in the Near East and India . *V. basalis* and *V. auraria* have been reported from Punjab (Raw, 1954) and *V. cincta* from Madras as serious pest of *A. cerana indica* (Subbiah and Mahadevan, 1957). Ghosh (1924) recorded the severe attack of *V. auraria* on honeybee colonies.

In Himachal Pradesh, there were four species of the predatory wasps viz. *V. magnifica (=V. mandarina), V. cincta (=V. tropica)* , *V. auraria (=V. velutina),* and *V. basalis* which attack the colonies of *A. mellifera* and *A. cerana* in Solan (Sharma, 1979) and in Kangra area (Sharma *et al.*, 1985). They become active during monsoon season and their activity continues till the advent of winter season. However, later on one more species, *V. orientalis* was added to the list by Sharma and Raj (1988) from the plain areas of the state.

Nature and extent of damage

Bees may be attacked by the wasps both i0n the field and at the entrance of the colony. In some circumstances i.e when there are no guard bees or the colony strength is weak they enter the hive and destroy brood and honey stores. Generally, the crop content of the captured bee is eaten and the thoracic region is taken to the hive for the brood as food. *V. auraria* which is a regular visitor in the apiaries causes immense damage to the bees and has been reported to catch the bees during flight (Ghosh,1924). Its visits started early in the morning at 0515 h, where it waited for the bees to come out of the hives, then the attack started slowing down at 1130 h and picked up again after 1530 h. The attack started decreasing after 1800 h. The

wasp attacked mainly the incoming foragers and after catching the bees, they settled on a near by foliage, behead the bee and fed upon the crop after biting open the thorax, then it bit off the legs and wings for taking the thorax to its nest. The colonies due to its severe attack become weak and sometimes the bees abscond leaving behind lot of honey and brood.

The mode of attack of *V. auraria* in the apiary was chasing a particular prey continuously around the hive, flying under the hive or by the side and charging at the incoming or outgoing worker. Sometimes it hovered in front of the hive with its back towards the hive, waiting for the forager or would make a single pass in front of the hive and scoop the forager on its way. After it had caught the forager, it flew to a nearby bush to make a meal out of it. Nearly 50 wasp visits were observed to take place at a time with the total of 150-350 wasps throughout the day in Kangra and in a single day, it was obseved to lift away upto 150 worker bees from the apiary in Kangra (Sharma *et al.*, 1985).

Sharma *et al.*(1985) reported that *V. mandarina* starts its attack as early as 0700 h and it gives an advance warning of the attack by a loud noise of its wing vibrations. On its final descend on the colony's alighting board it makes a loud clicking noise with its mandibles and scratches the alighting board. Then it goes on catching and cutting bees with its mandibles . A single wasp of the species could devour around 200 *A. mellifera* worker bees in 5-10 minutes. Matsuka (1968) and Matsuura and Sakagami (1973) observed that *V. mandarina* was a serious menace to Japanese apiculture. It has been reported to attack *A. mellifera* colonies in groups of 25-30 wasps. In South Japan *V. mandarina* has been reported to kill 5,000-10,000 bees out of a total population of 15,000-30,000 per hive and only one or two wasps died during encounter with the bees (Sakagami and Matsuura, 1972). They also observed that when the wasp attacks in groups of 25-30, killed the bees @ 1 bee/14 sec. Adlakha (1975) reported that as many as 20-25% of bee colonies are lost in Himachal Pradesh due to the attack of this predatory wasp.

Subbiah and Mahadevan (1957) reported *V. cincta* as a serious pest of *A. cerana indica* in South India where this wasp frequently visited bee hives on cool and cloudy mornings from June to December. During this period, the breeding activity of the bees is low and the wasp attack further weakens the colonies so that either the bees desert their nests or they perish.

Relation to rainfall and temperature

There is little information available on population dynamics of many species of the social wasps. The abundance of wasps during certain years has been related directly to rainfall and temperature in April to early June (Long *et al.*, 1979; Akre and Reed, 1981). Excess rainfall and low temperatures during these months cause many colonies to fail. Conversely, dry, warm weather during April, May and June tends to favour survival of the colonies and results in outbreak populations as experienced in the Pacific north west during different years (Mac Donald *et al.*, 1976; Akre and Reed, 1981).

Beirne (1944) and Fox Wilson (1947) studied the phenomenon of cycles of yellowjacket abundance and scarcity from year to year and emphasized the importance of climatic factors. Beirne (1944) suggested that heavy rainfall in May and June decreased the wasp population but rainfall alone does not account, so he suggested that some additional factors might also be operating. Wafa (1956) concluded that there was a negative correlation with the day temperature and positive correlation with the temperature of the previous night on the visitation of the wasps in Egypt.

Control

For the control of the predatory wasps, various researchers in different parts of the world have tried different methods. Matsuura and Sakagami (1973) outlined six procedures used by the beekeepers in Japan to combat the hornets. These include killing of the individual hornets with a stick/flappers visiting the apiary, destroying

hornet nests by burning, fumigation etc., bait trapping or mass poisoning by presenting the hornets with poisoned baits with malathion or some other insecticide (which may be carried to the hives and distributed among the members presumably by trophyllaxis). Hindering the wasps at the entrance by using cones, lattices and screens permit the bees to enter while they retain the hornets. Using protective screens which interfere with the approach of the hornets and decrease suicidal counterattacks by the bees.

In Egypt, Mellor (1928,1929) recommended trapping, catching and killing of the wasps in apiary and chemical control by fumigation of nests or using poisoned honey baits. Blake (1966) reported that women run into the apiary, swinging a stick with a ten-inch-square piece of tin to kill the hornets. Adsay (1950) reproted an even more unusual method of control in Turkey where the Denzili chickens are raised on regular chicken feed mixed with dead hornets, these chickens are then released in the apiary where they gradually begin to feed on the live hornets at which point their food is drastically reduced. The chickens are not affected by the bee stings.

In Australia, Rye (1986) tried different chemical treatments for controlling *V. germanica* and *V. vulgaris*. In Germany, Hirschfelder and Landesanstat (1952) tried to control bee killer wasps by covering an area having 250 nests with benzene hexachloride powder but it did not work well so diethyl paranitrophenyl thio phosphate (E605) was tried for dusting which had no ill effect on bees. Later on Ujinager (1995) used spray type pesticide 'tiachi knock' for the control of vespine wasps. However, Kulanin (1974) reported that 1% aqueous suspension of Sevin 85 WP @ 100-115 ml/nest was most effective for the control of *V. orientalis* and *Polistis gallicus*.

In the category of synthetic chemical attractants, Davis *et al.* (1975) tried different chemicals like heptyl butyrate, octyl lutyrate , monyl tiglate etc. as attractants and reported that α and β unsaturated esters in traps provided useful control against wasps without harming bees.

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In India, the wasps were tried to control by burning the nests with kerosene torches after sunset, fumigation with calcium cyanide @ 200-250 grams per nest after plugging the entrance hole or using aluminium phosphide (Celphos) with 0.5 gram tablet per nest (Bhutani, 1950; Robin and Dupers, 1957; Subbian and Mahadevan, 1957; Singh, 1962; Sharma *et al.*, 1985). Spray of 0.5% parathion was tried to kill the wasps but did not provide immediate control as the wasps were active even after 3-4 days of spraying (Subbiah and Mahadevan, 1957).

According to Wafa *et al.* (1969), out of the seven honey baits prepared from different insecticides, DDT+lindane bait was found to be the best in the laboratory and malathion+honey bait at the nest gate in field. Wagner and Reierson (1969) incorporated different insecticides in fish flavoured baits @ 0.25%. For example, 'Bagon', carbaryl, dichlorvos, malathion, dieldrin, diazinon and trichloroform were highly repellent, ronnel, keptone and chlordane moderately repellent and crotonic acid esters of hexyl or heptyl alcohol gave consistent results for the genus *Vespula*. According to them, the use of 450 gm bait (0.5 - 1% mirex bait) gave year long control. Rivnay and Bitinsky (1949) found that bait containing water, talcum powder and minced meat in the ratio 1:1:2 poisoned by 1% thalium sulphate later replaced by lead arsenate was successful for the control of the predatory wasps.

Mizoue (1983) used ether extracts of the workers of *V. mandarina* which attracted both males in September to October and workers in October to November of the species. An acidified fraction of the extract was particularly attractive which contained hydrocarbons, organic acids and esters.

Sharma *et al.* (1979) compared the relative attractiveness of different baits. In case of meat bait they found attractancy in the order of untreated meat (100% attractancy), meat+0.25% trichloroform had 59% attractancy, meat+0.5% trichloroform had 20% attractancy but with 1% chloroform, lindane or chlordane attractancy was low. Mishra *et al.*, (1989) tested fruit baits like over ripe pear (cvs. Nashpati and Baggugosa), apple (cv. Royal Delicious), plum (cv. Santa Rosa), peach (cv. July Elberta) and mango (Seedling) for their attractancy and found that nashpati

was the most attractive (8.88 wasps) followed by pear (8.80 wasps), peach (7.05 wasps) and apple (5.55 wasps) per 15 minutes.

Wang *et al.* (1985) reported that to smear captured hornets with a poison dose @ 1-2 gm per hornet and release them was most effective method to control the predatory wasps. These hornets on returning to the nest distributed the poison in whole colony. Mishra *et al.*(1989) have developed a new approach to control predatory wasps i.e. the 'capsule cup' technique using trimmed capsule filled with poison bait prepared by adding the desired concentration and amount of insecticide-acetone solution to 'gur' (a refined form of jaggery) followed by vigorous mixing and air drying of the acetone. The load was fixed to the thorax, which the wasps carried to the nest and provided effective control. Baits were prepared with 100, 200, 300, 500 or 1000 mg fenitrothion (technical grade) kg^{-1} gur. A load of 110 mg poison bait could easily kill 30-35 wasps. In two field experiments, by sending 25 and 16 loads of poison cups, respectively, nests of *V. cincta* were completely destroyed.

Hive modifications

Various investigations have been carried to control the predatory wasps by modifying the hives in India. For example, use of queen guard or queen gate 12.7x5.1 cm (Dave, 1943) or 12.5x5x0.4 cm size at hive entrance (Sharma *et al.*,. 1979) was found to be useful in checking the attack of predatory wasps and thus reduced their severity. Subbiah and Mahadevan (1957) suggested the removal of alighting board to check the damage caused by the predatory wasps.

Different types of traps have been devised by various research workers in different parts of the world to check the attack of wasps on honeybee colonies by attracting them in such type of traps. Wafa *et al.* (1969) trapped the wasps with honey comb baits which were distributed in the Egyptian apiary to attract the wasps. When the wasps were attracted on the combs, they were shaken into the trap and the

door was quickly shut. Monthly catch by this method was 23,900 wasps/trap in October,1962 and 13,095 wasps/trap in October,1963.

A wasp trap designed by Kshirsagar (1971) was reported to catch 100 wasps per day in the experimental apiaries at Kangra and Kashmir region of India. Longo (1980) used successfully two types of traps to catch wasps near hives. He used a piece of yellow plexiglass, 210 X 150 mm, covered with an adhesive to which the insects stick, and a yellow plastic bottle with a small hole cut in the side containing 10% solution of hydrolysed protein (Buminol) to attract the wasps and pyrethrin, which killed them.

In Pakistan, Muzaffar and Ahmed (1986) placed plastic jars on top of the hives containing a solution of 50% sucrose which provided some degree of control. Ibrahim and Mazeed (1967) tested seven types of traps and the trap with honey bait gave the best results.

Reierson and Wagner (1975) devised a plastic trap to collect and preserve various species of yellow jackets to monitor seasonal activity in four southern and central California localities.

In India, beekeeping industry with *A. mellifera* is facing serious problem of predatory wasps in some regions of the country. Regardless to all the above measures for the control of predatory wasps, there is no effective and reliable measure or control stratergy developed so far which can be adopted by the beekeepers to protect their colonies from these wasps.

CHAPTER 3

MATERIALS AND METHODS

Present investigations were carried out in the apiary of Department of Entomology and Apiculture, Dr. Yashwant Singh Parmar University of Horticulture and Forestry at Nauni (1256 metres above the mean sea level, 30^0-50' N latitude and 78^0-8' E longitude). The apiary had more than 50 *Apis melllifera* colonies, where observations were recorded on the visitation of workers and fecundated queens of different species of predatory wasps. Weekly data on temperature, humidity and rainfall were taken from the records maintained by the Department of Soil Sciences of this University.

3.1 Fecundated Queens

The data were recorded on the number and period of visits of the fecundated queens of the wasp regularly from March to June throughout the day. The visiting foragers were collected and dissected to confirm whether these were queens or workers. Some of the foragers were also collected from the flowers.

3.2 Incidence

Incidence of predatory wasps, *Vespa auraria, V. basalis*, *V. cincta* and *V. magnifica* was recorded in the apiary from the month June to December. Observations on the wasp visit were recorded for 10 minutes at hourly intervals from 0600 h to 1800 h. From this hourly data, the peak incidence of attack was standardized for recording observations for further studies. Later the observations were confined to forenoon (0900-1000 h), noon (1100-1200 h) and afternoon (1600-1700 h) in different seasons.

However, these timings were adjusted accordingly in relation to temperature in autumn and winter seasons i.e. 0930 h - 1030 h in forenoon, 1130 h - 1230 h in noon, 1630 h - 1730 h in afternoon for autumn season. and 1000 h - 1100 h in forenoon, 13000h - 1400 h in noon and 1500 h - 1600 h in afternoon for winter season. Such observations were recorded twice a week. Similarly, weekly record of different wasps species in the apiary was maintained in 1997. The data collected was pooled and monthly averages were computed. The number of wasps visiting the apiary was counted by flapping and killing, those wasps which could not be flapped were not counted as they made repetitive visits but during the last 5 minutes of the observation hour, all flapped and non flapped wasps were counted as the non flapped wasp could not make its next visit in such a short span of time.

3.3 Nature and Extent of Damage

The nature of attack of predatory wasps was noticed by visual observations during thier visit to catch the bees. The post capturing behavior of the wasp with the bee was noticed only for those wasps which sat on the smaller trees or bushes near the colonies. Extent of damage was studied by counting the number of bees lifted during the peak incidence hours in morning, afternoon and evening. During these observations, no wasp was flapped.

3.4 Relation to rainfall and temperature

From the data on rainfall and temperature (maximum and minimum), relation between these parameters and incidence of wasps was worked out. For this purpose, weekly means of rainfall and temperature(s) in 1996 and 1997 were calculated for rainfall, minimum temperature and maximum temperature during January to April, respectively. The graphs obtained for these months were studied to deduce any relation between the incidence, rainfall and temperature(s).

3.5 Control of predatory wasps

Studies on the control of predatory wasps were carried out by conducting the different experiments.

3.5.1 Hive modifications

Various type of hive modifications were tried to protect the honeybees by creating hindrance so as to keep the wasps away from the colonies. These modifications were as follows:

3.5.1.1 Using wire gauge cage

Wire gauge cage having size 2.5 x 2.5 cm for each smallest unit made of the dimensions 15 x 15 x 15 cm (l **x** b **x** h) was fixed in front of the hive entrance. The number of bees lifted from the hives having the modification was recorded for 10 minutes and similar record on the control hives was also maintained. The experiment was conducted on three colonies at a time.

3.5.1.2 Using bird scaring ribbons

Bird scaring ribbons , 1.5 cm wide, were used in front of the hives in horizontal way covering 5 hives. The ribbons were fixed at 5 cm apart from each other with a total of 6 long strips tied on bamboo sticks and these were put in front of the hives at a distance of 5 cm from the entrance. In second experiment, the strips were arranged parallel to each other in vertical position, 3 cm apart from each other and fixed on the bamboo sticks running from top of the hive to the ground at a slight angle from top to base. The observations were recorded for 10 minutes both for control and the modification.

3.5.2 Attracting and trapping the predatory wasps

Another type of control measure was tried by attracting and trapping the predatory wasps in jars and traps containing honey syrup, fermented honey and extracts of predatory wasps and bees alone or in combination.

3.5.2.1 For this purpose, the honey was diluted to 24 TSS and fermented with the culture of *Saccharomyces cerevisieae* (yeast). The fermented honey was kept upto 1/3 level in jars and placed at different locations in the apiary.

3.5.2.2 Honey syrup diluted with water (1:2, 1:3 and 1:4) was also tried in the apiary. The diluted honey syrup was kept upto 1/3 level in jars and placed at different locations in the apiary.

3.5.2.3 Fermented honey with extracts of predatory wasps and bees from Soxhlet's apparatus was also used in similar manner.

The data were recorded on the basis of number of wasps caught in these jars per day as well as on dead bees.

Extraction was done in Soxhlet's extraction apparatus (150 ml) by using different solvents like hexane, diethyl ether and acetone. For extraction purpose, 25-30 *V. auraria* and 50-60 *A. mellifera* workers were used. Similarly extractions of head, thorax and abdomen of the wasps was done. The extraction was carried out by using 70-80 ml of the extracting solvent at different temperatures viz, 30, 50 and 60°C for 3 hours with 5-6 cycles of the solvent through the extraction chamber. Extraction experiments were also tried at 0-5°C with crushed wasps kept in 50-60 ml extracting solvent in a conical flask placed in the refrigerator overnight. These extracts so obtained were tried by drying, without drying the solvent or in

combination with fermented honey. The results were recorded by counting the number of wasps and honey bees trapped inside the jars or in petriplates with the extracts, placed in front /top of the hives at three different locations of the apiary respectively.

3.5.3 Meat and Fish baits

Fresh fish and meat (1 kg each) were brought and stored in the refrigerator on. Petriplates containing 70-80 grams meat and fish each were placed on top of the hives in the apiary. For each bait three replications were used, placed in different locations in the apiary and observations were recorded on the number of wasps attracted to these petriplates.

Statistical Analysis

The data recorded were subjected to statistical analysis wherever considered essential . The difference exhibited by the treatments in various experiments was tested for their significance as per the methods suggested by Gomez and Gomez (1984).

The abbreviated titles of the publications in the 'references' are indicated according to "**List of Serials, 1974**".

CHAPTER 4

EXPERIMENTAL RESULTS

Results of the studies conducted on the incidence, damage to bees and control of predatory wasps in the apiary are as follows:

4.1 Incidence (1996)

In the present investigations, studies were conducted on the incidence of predatory wasps in the university apiary at Nauni, Solan. The weekly observations recorded from the second week of June 1996 on the visitation of *V. auraria* are presented in the Table1.

Table 1.

Number of *V. auraria* visiting the apiary of *A. mellifera* at Nauni, Solan during 1996.

Month	Wasps per day (Mean±S.E)			
	I Week	II Week	III Week	IV Week
June	--	64..4±4.05	74.6±2.47	89.1±2.65
July	90.5±2.63	106.4±3.17	140.2±11.83	125.2±19.70
August	171.6±10.91	205.7±30.02	212.1±5.40	219.1±26.89
September	282.4±9.31	260.1±3.15	263.1±3.14	189.6±6.89
October	239.1±3.77	161.7±1.76	190.9±3.76	186.6±4.29
November	155.1±2.95	149.1±2.60	121.4±3.50	111.6±6.57
December	83.1±4.50	40.3±3.07	16.0±1.80	0

Incidence data showed that during second week of June 64.4±4.05 *V. auraria* visited the apiary per day. In the first week of July, the incidence increased to 90.5±2.63 wasps per day and by the last week of July it was 125.2±19.70. In

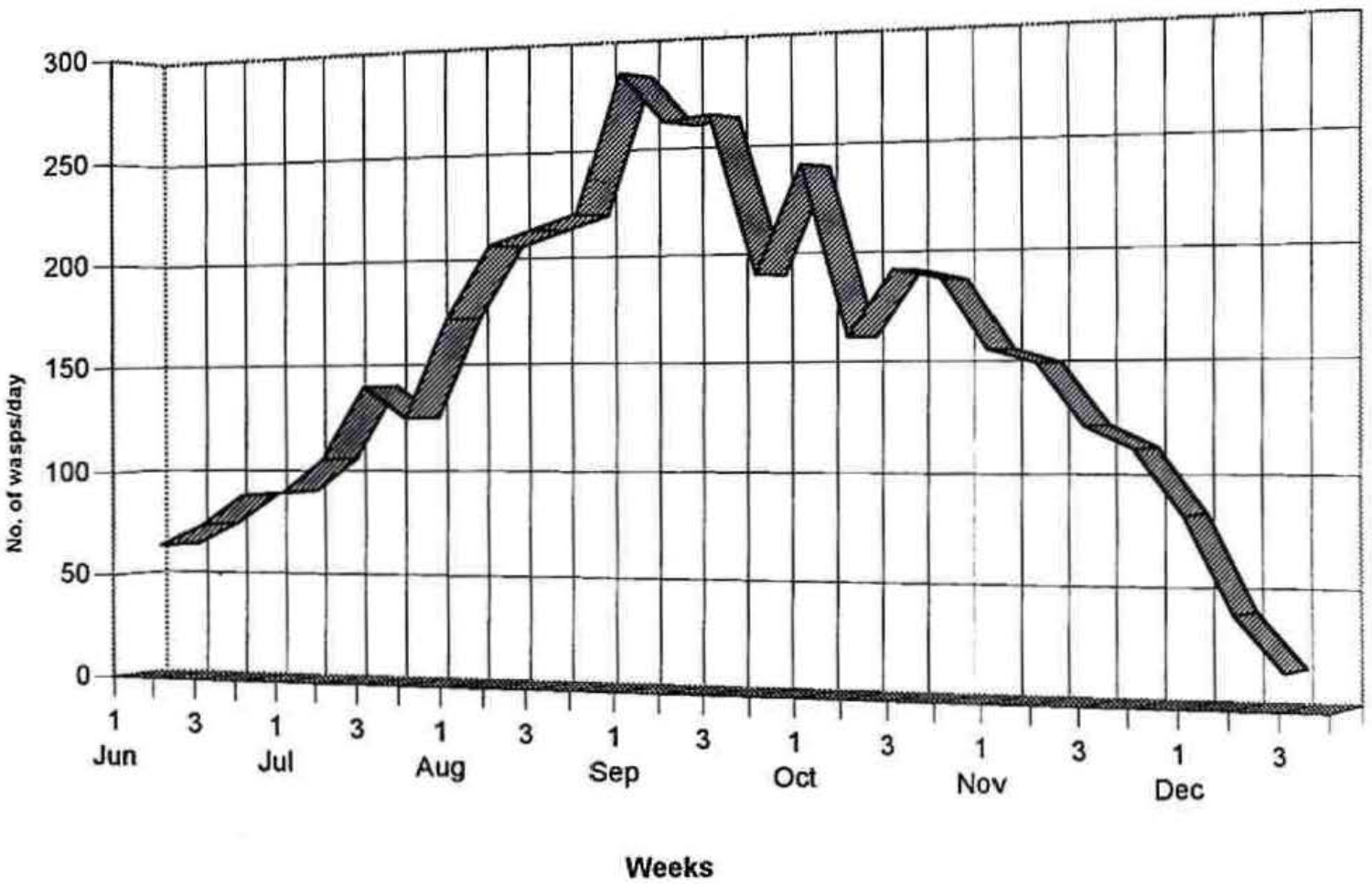


Figure 1 Incidence of *V. auraria* in the apiary during 1996

begning of August, there was about three fold increase in the incidence, as 171.6±10.91 wasps per day were counted during the first week in comparison to June. The increase continued till first week of September, with the peak reaching upto 282.41+9.31 wasps per day (Figure 1). Thus that maximum number of wasps recorded in the months of September and October, after which there was a regular declining phase in the apiary. and the wasp count decreased to 16.0±1.80 wasps per day in the third week of December. With the further fall in temperature during December, the incidence decreased and it came down to negligible by the end of the month. *V. magnifica* visitation was not recorded in the apiary during 1996.

4.1.1 Queen visitation

During 1997, the visitation of queens was also recorded in the apiary from March to June regularly throughout the day and is presented in Table 2.

Table 2.

Number of *V. auraria* queens visiting the apiary of *A. mellifera* at Nauni, Solan during 1997.

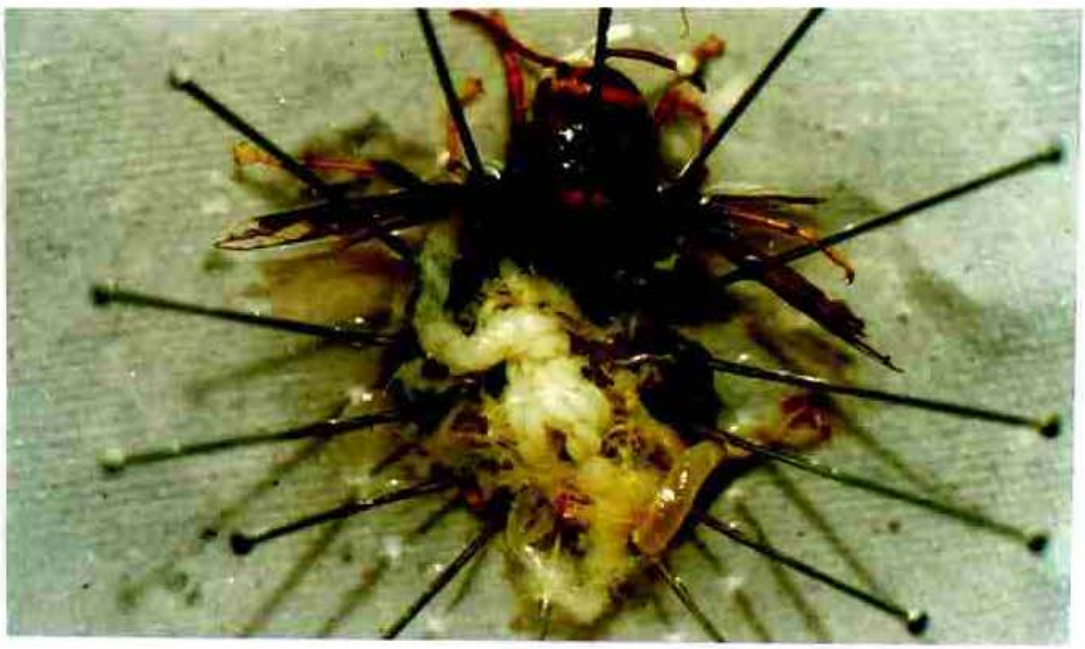
Observation period	Number of queens visited
March	2
April	4
May	3
June (upto 15th)	4
First queen visited on 10th March Last queen visited on 15th June	

The first queen of *V. auraria* was observed in the apiary on 10th March and second on 20th March, 1997 which were caught and confirmed by dissection (Plate I). In all, 13 queens were flapped and collected between March and mid June. During this period of observation no *V. magnifica, V. basalis* and *V. cincta* queens were noticed in the apiary.

PLATE-I

V. auraria nest in cup stage (single tier)

V. auraria nest (closed) in later stage(s)



Dissected *V. auraria* queen showing the ovaries with eggs in various stages of development

4.1.2 Incidence of predatory wasps during 1997

The incidence of predatory wasp workers in the apiary of *A. mellifera* for the year 1997 is compiled in Table 3.

Table 3.

Incidence of predatory wasps in the apiary of *A. mellifera* at Nauni, Solan during 1997.

Month	Observation Period	Number per day			
		V. auararia	*V. basalis*	*V. cincta*	*V. magnifica*
June	III Week	8	0	0	0
	IV Week	12	0	0	0
	Mean±S.E	10.0±1.41			
July	I Week	16	0	0	0
	II Week	27	0	0	0
	III Week	74	0	0	0
	IV Week	147	0	0	0
	Mean±S.E	66.0±25.79			
August	I Week	155	0	0	0
	II Week	146	0	0	0
	III Week	210	8	0	0
	IV Week	180	11	0	0
	Mean±S.E	172.0±12.43	9.5±0.41		
September	I Week	226	13	1	0
	II Week	254	12	3	0
	III Week	260	18	6	0
	IV Week	243	20	8	0
	Mean±S.E	245.7±6.46	15.7±1.67	4.5±1.35	
October	I Week	157	23	7	0
	II Week	179	16	4	1
	III Week	150	29	8	0
	IV Week	133	38	9	1
	Mean±S.E	154.7±8.25	26.5±4.04	7.0±0.93	
November	I Week	102	41	4	1
	II Week	74	37	2	0
	III Week	68	33	0	0
	IV Week	40	17	0	0
	Mean±S.E	71.0±11.01	29.5±4.92		
December	I Week	10	8	0	0
	II Week	6	0	0	0
	Mean±S.E	8.00±1.41			

In May, 1997, the incidence of *V. auraria* was almost negligible, as only one to two wasps visited the apiary. In early June only three to five *V. auraria* visited the

apiary and no other wasp species were seen in the apiary during this period. Data on the worker visitation presented in the Table 3 reveals that by the end of June, frequency of visits of *V. auraria* had reached upto 10.0±1.41 wasps per day. In July, the population of workers increased to 66.0±25.79 wasps per day, The population was maximum (245.7±6.46 wasps per day) in September. After this, there was continuous reduction in the visitation of predatory wasps during October and November and the incidence was almost negligible by December 1997.

Later *V. basalis* started visiting the apiary in the second fortnight of August. Its visitation rose from 9.5±0.41 wasps per day in August to a maximum of 29.5±4.92 wasps per day in November. The third species, *V. cincta* made its first visit in the first week of September. Its mean population increased from 4.5±1.35 wasps per day in September to 7.0±0.93 wasps per day in October (Figure 2).

The incidence trend in 1996 and 1997 indicated similar period of appearance of *V. auraria* in June, increasing to maximum in the month of September and declining in December to negligible (Figures 1,2). The observations on percentage of different wasp species visiting the apiary showed that there was 79.96% attack of *V. auraria*, 24.66 % of *V. basalis* and 0.38 % of *V. cincta* throughout the year (Figure 3).

During 1997 only three *V. magnifica* workers visited the apiary. The observations showed that the first worker visited on 12th October while the last was observed on 2nd November in the apiary.

4.2 Nature and extent of damage

All the four species of wasps viz. *V. auraria, V. magnifica, V. basalis* and *V. cincta* were noticed in the *A. mellifera* apiary (Plate II). The nature and extent of damage by different species of the predatory wasps is described below:

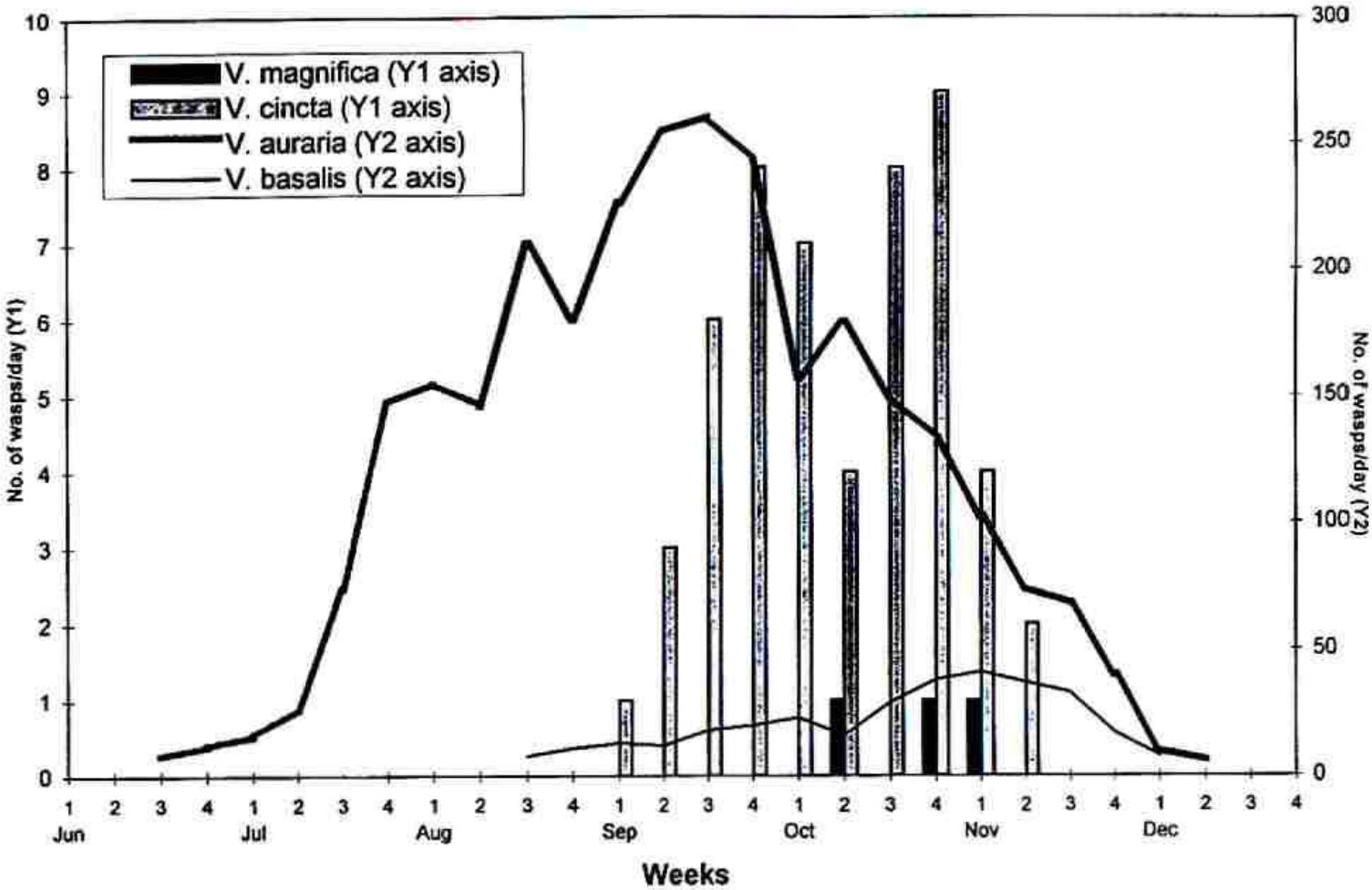


Figure 2. Incidence of predatory wasps in the apiary of *A. mellifera* at Nauni, Solan during 1997.

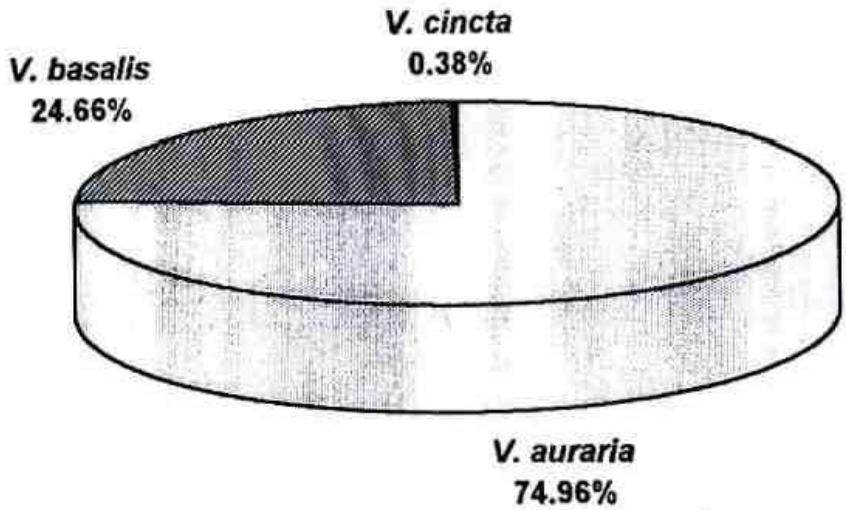
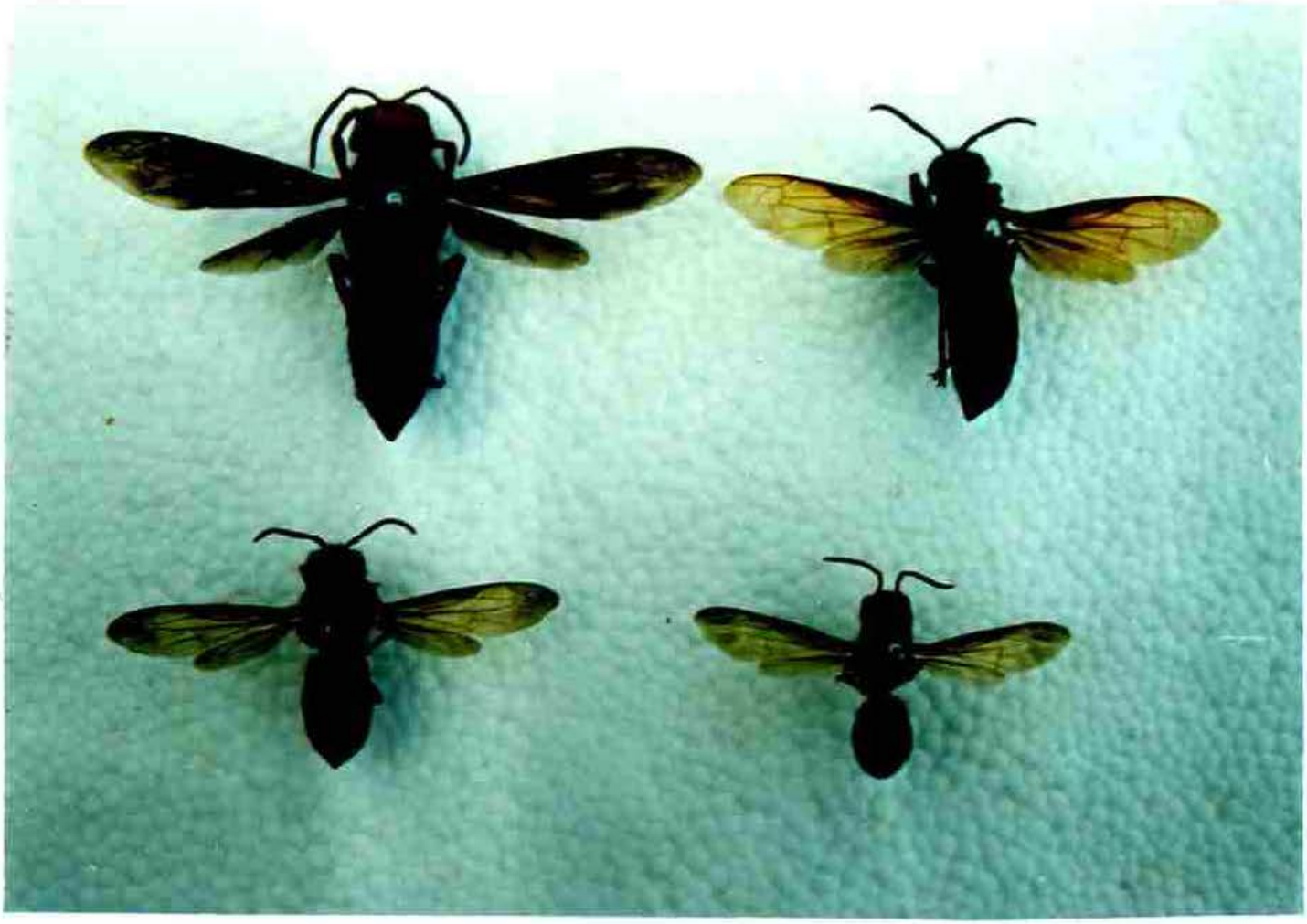


Figure 3. Percentage incidence of different wasp species

PLATE-II



Predatory wasp species visiting *A. mellifera* apiary at Nauni, Solan		
Top, Left to right	*V. magnifica*	*V. cincta*
Bottom, Left to right	*V. auraria*	*V. basalis*

4.2.1 Behaviour of *V. auraria*

V. auraria captured the bees on wings and also caught them from the alighting board. Mainly the incoming field force and the guard bees fell prey to the wasp. The wasps hovered under the alighting board or at the sides waiting for the incoming forager or it hovered just in front of the hive entrance with its back towards the hive waiting for the prey. Sometimes it flew in front of the hives scooping at the bees which came in its way and caught it with its powerful legs. When the foraging activity was minimum the wasp tried to lift the guard bees from the alighting board or the bees which attacked it., and took it to a nearby bush or branch of tree to make a meal out of it. Some of the bees when attacked by the wasps managed to escape due to their swiftness and high flight speed. *V. auraria* never hovered consistently in front of the colony particularly when the bees were alert. In such cases, they changed their flight to another hive. As many as 1-5 wasps were observed hovering in front of a single colony, sometimes wasps hovering in front of the same hive were aggressive to each other. Weak colonies were more susceptible to the attack.

4.2.2 Behaviour of *V. basalis*

V. basalis also hovered in front of the hive but due to its comparatively slow and sluggish behaviour, it rarely captured the bees on wings. It restricted its flight to the ground level where it tried to catch the bees knocked down on ground or the malformed workers which have been discarded by the bees.

4.2.3 Behaviour of *V. cincta*

V. cincta was never observed to take any bee but it made continuous patrolling visits to the apiary. It hovered for some time infront of the hive and in the

absence of the guard bees it tried to enter the hive. It made this visits probably in search of nectar or honey fron the hives.

4.2.4 Behaviour of *V. magnifica*

V. magnifica is the most dreaded among the predatory wasps because of its high devouring capacity and it can kill lot of bees in a short span of time. There were three *V. magnifica* workers found in the apiary in 1997. The wasps hovered around the apiary for some time and then they descended on the *A. mellifera* colony by making loud clicking noise with their powerful mandibles. These were flapped before they could begin slaughtering the bees on the alighting board.

4.3 Relation to Temperature and Rainfall

The compiled data on minimum temperature showed that it was higher in March-April,1996 as compared to 1997 for the same months. The temperature ranged from 8.7 to 12.3 °C and 11.7 to 16.1 °C during March and April,1996, respectively, whereas it was 8.7 to 10.0 °C and 9.3 to 14.7 °C in the respective months of 1997. However, the rainfall during April-May,1996 was lower than the same months during 1997. In 1996, rainfall was 0 to 1.8 mm in April and 0 to 8.6 mm in May, while it was 0 to 61.0 mm and 0 to 36.6 mm for the respective months during 1997 (Appendix).

Since, March - April is the emergence period of the overwintering wasp queens, while April -May is the period of establishment of nests by these queens. Thus from the data it is clear that higher minimum temperature and lower rainfall during 1996 might have resulted in early emergence and establishment of the wasp queens, which caused early incidence of the wasps during this year as compared to 1997.

4.4 Extent of Damage

The damage caused to the colonies was mainly by *V. auraria* in the apiary of *A.. mellifera* which is presented in the Table 4.

Table 4.

Extent of damage (number of bees lifted) caused by *V. auraria* to *A. mellifera* during different hours of the day in 1997.

Observation period		Number of bees lifted (30 minutes count)			
		1100-1130	0130-0200	0300-0330	Mean±S.E
July	III Week	39	48	36	41.0±1.70
	IV Week	42	64	31	45.6±4.57
August	I Week	59	71	80	70.0±2.86
	II Week	72	85	69	75.3±2.31
	III Week	89	96	43	76.0±7.83
	IV Week	84	43	64	63.6±5.58
September	I Week	102	84	74	86.6±3.86
	II Week	111	78	93	94.0±4.50
	III Week	116	99	72	82.3±6.04
	IV Week	120	79	90	96.3±5.77
October	I Week	76	85	40	67.0±6.48
	II Week	98	82	36	72.0±8.76
	III Week	46	61	32	46.3±3.94
	IV Week	39	58	23	40.0±4.76
November	I Week	29	39	15	27.6±3.28
	II Week	25	19	20	21.3±0.87
	III Week	19	8	13	13.3±1.81
	IV Week	10	16	9	11.6±1.82
Mean±S.E		69.2±1.92	61.9±1.48	46.6±1.49	

The data collected showed damage to the bees from July to November. In July, the extent of damage was low with an average of 41.0±1.70 to 45.6±4.57 bees being lifted per 30 minutes during peak periods of activity of the wasps. During this month the number of wasps was also low i.e., 66.0±25.79 wasps per day (Table 3). With the increase in frequency of wasps visitation the number of bees lifted also gradually increased. In August, ~~s third week~~ maximum number of bees lifted was

76.0±7.83 and in September it was 96.3±5.77 bees per 30 minutes in different observation periods from forenoon to after noon. With the decrease in the frequency of wasps visitation the number of bees lifted also decreased and came down to 11.6±1.82 bees per 30 minutes by the end of November and was almost negligible in December. The wasps could easily hunt the prey within 30 seconds during peak activity hours.

4.5 Initiation and Cessation of the attack

The data on the time of initiation and cessation of *V. auraria* are presented in the Table 5.

Table 5.

Time of initiation and cessation of the attack of *V. auaria* in the apiary

Date	Initiation time (h)	Cessation time (h)
09-08-96	0616	1925
12-08-96	0551	1930
15-08-96	0605	1912
17-08-96	0545	1929
20-08-96	0556	1900
Range	0545-0616	1900-1930

The wasp started visiting the apiary as early at 0545-0616 h in the morning and the attack continued till 1900-1930 h in the evening during August,1997. Wasps which once visited the apiary to hunt rarely returned without the prey except those wasps which visited after the cessation of the bee activity in the evening.

4.6 Control of predatory wasps

Results compiled on various methods tried for the control of the predatory wasps are given below.

4.6.1 Flapping

It is a traditional method to kill the predatory wasps visiting the apiary and to protect the bees from them. Data in Table 3 on the flapping of the wasps revealed that in the begining of the incidence, average number of 10.0±1.41 wasps per day were killed during the month of June. This number of wasps being flapped gardually increased to 66.0±25.79 in July with the increase in their frequency of visitation. maximum number of wasp were flapped in September (245.7±6.46 wasps per day)) and after this period the number gradually declined in November to 71.0±11.01 wasps per day. In December the number of wasps flapped was almost negligible. Thus, present studies revealed that the population of wasps follows a normal trend of buildup from the begining of the incidence, reaching its peak and then declining to the minimum irrespective of the flapping/killing practised in the apiary.

4.6.2 Hive modifications

4.6.2.1 Use of wire gauge cage (size 2.5X2.5 cm) at the hive entrance

Results collected with hive modification to create hinderance for the predatory wasps are as under:

Table 6.

Effect of fixing wire gauge cage (size 2.5 X 2.5 cm) at hive entrance on number of bees lifted by *V. auraria*

Date	Number of bees lifted (10 minutes count)			
	Caged hives		Control hives	
	Weekly average	Monthly average	Weekly average	Monthly average
15-09-97	1.7±0.31		1.3±0.31	
22-09-97	2.3±0.16	1.5±0.23	1.0±0.47	1.3±0.09
29-09-97	0.6±0.31		1.7±0.31	
05-10-97	1.3±0.16		1.0±0.27	
12-10-97	1.3±0.15	1.3±0.06	2.0±0.00	1.1±0.18
19-10-97	1.0±0.00		0.0±0.00	
26-10-97	1.7±0.16		1.3±0.31	
03-11-97	0.7±0.16	0.7±0.16	0.3±0.16	0.3±0.16
Treatment Mean	1.3±0.07		1.1±0.08	

Non significant

Data indicate that the average number of bees lifted from the hives provided with the wire mesh cage modification at the entrance was 1.3±0.06 bees per 10 minutes while from the control hive (without wire mesh cage modification) was 1.1±0.18 bees per 10 minutes from 5th to 27th October, 1997. Statistical analysis of the data revealed that there was no significant difference in the number of bees lifted from the hives with wire mesh cage modification and the control hives.

4.6.2.2 Use of bird scare ribbons in front of the hive entrance

Table 7.

Effect of bird scare ribbons used in front of bee colony on number of bees lifted by *V. auraria*

Date	Number of bees lifted (10 minutes count)			
	Ribboned hives*		Control hives	
	Weekly average	Monthly average	Weekly average	Monthly average
28-09-97	2.0±0.47		1.7±0.16	
29-09-97	2.0±0.54		1.3±0.16	
30-09-97	2.3±0.31	1.9±0.09	3.0±0.27	1.8±0.25
31-09-97	1.3±0.31		1.3±0.16	
01-10-97	2.0±0.27		2.3±0.41	
02-10-97	1.3±0.63		2.3±0.31	
03-10-97	0.7±0.00	1.8±0.11	1.3±0.16	2.1±0.09
04-10-97	2.3±0.51		1.7±0.79	
05-10-97	2.0±0.00		2.2±0.54	
06-10-97	2.7±0.57		3.0±0.47	
Treatment Mean	2.0±0.06		1.9±0.06	

Non significant

* Pooled data for horizontally and vertically fixed ribbons on 5 hives each.

The number of bees lifted from the hives provided with the bird scare ribbon modification in front of the entrance was 1.8±0.11 bees per 10 minutes while from the control hive (without bird scare ribbon modification) it was 2.1±0.09 bees per 10 minutes during the first week of October, 1997. Statistical analysis of the data revealed that there was no significant difference in the number of bees lifted from the above experimental hives.

4.6.3 Protection of honey bees by attracting predatory wasps

4.6.3.1 Use of Fermented honey

This experiment was conducted to control the predatory wasps by attracting them towards fermented honey. The data are presented in Table 8.

Table 8.

Number of wasps and bees trapped in jars per day containing fermented honey in the apiary at Nauni,1997.

Date	Number trapped per day				
	V. auraria	*V. basalis*	*V. cincta*	Total wasps	Bees
25-09-97	0	1	3	4	3
26-09-97	2	1	2	5	1
27-09-97	3	0	2	5	2
28-09-97	0	2	3	5	5
29-09-97	4	0	1	5	2
30-09-97	2	2	2	6	3
31-09-97	3	0	3	3	3
01-10-97	1	0	1	2	5
02-10-97	0	0	0	0	3
03-10-97	5	2	2	9	0
04-10-97	1	0	3	4	0
05-10-97	3	1	1	5	4
06-10-97	2	2	5	9	3
07-10-97	2	0	4	6	4
Mean±S.E*	2.0±0.10	0.6±0.10	2.6±0.18	5.0±0.45	2.7±0.12

* Pooled data for three jars

Studies conducted on the control of predatory wasps by attracting and trapping them in jars containing fermented honey showed that on an average 5.0±0.45 wasps with a range of 0 to 9 wasps were attracted and killed by drowning in three jars per day in the last week of September to the first week of October,1997. Out of these, *V. auraria, V. basalis* and *V. cincta* were 2.0±0.10, 0.6±0.10 and 2.6±0.18 wasps per day, respectively while the number of their visitation was 245.7±6.46 , 15.7±1.67 and 4.5±1.35 per day, respectively, in September

month (Table 3). Thus the preference of wasps did not change if we use fermented honey as bait in the apiary.

4.6.3.2 Use of honey syrup

Control of the predatory wasps by attracting to the honey syrup is shown in the Table 9.

Table 9.

Number of wasps and bees trapped in jars containing honey syrup in the apiary at Nauni,1997.

Date	Number trapped per day				
	V. auraria	*V. basalis*	*V. cincta*	Total wasps	Bees
05-09-97	0	4	0	4	6
06-09-97	0	0	0	0	8
07-09-97	2	2	1	5	5
08-09-97	0	0	2	2	1
09-09-97	0	1	3	4	12
10-09-97	1	3	1	5	6
11-09-97	0	4	3	7	9
12-09-97	4	0	5	9	12
13-09-97	0	0	6	6	8
14-09-97	1	3	4	8	14
15-09-97	3	0	6	9	7
16-09-97	2	2	3	7	11
17-09-97	1	3	8	11	13
18-09-97	0	6	5	11	9
19-09-97	2	5	7	14	7
20-09-97	2	1	9	12	8
Mean±S.E	1.1±0.08	2.1±0.12	3.9±0.17	7.1±0.23	9.1±0.16

* Pooled data for three jars containing 1:2,1:3 &1:4 % honey syrup.

The experiment conducted with the honey syrup for the control of predatory wasps showed that on an average 7.1±0.23 wasps with the range of 0 to 14 wasps per day were trapped in jars in the month of September,1997. Out of these, *V. auraria*, *V. basalis* and *V. cincta* were 1.1±0.08, 2.1±0.12 and 3.9±0.17 per day,

respectively, while the visitation of the wasps was 245.7±6.46 , 15.7±1.67 and 4.5±1.35 per day, respectively, in the apiary. In addition to the wasps 9.1±0.16 bees per day(range: 1 to 14) were also trapped in these jars.

4.6.3.4 Ether extracts of the wasps and honeybees

The experiments conducted to attract predatory wasps to the extracts of *V. auraria* and honeybees obtained through Soxhlet's appratus by using different chemicals (acetone, hexane and diethyl ether) at different temperature(s) (0, 10, 30, 50, and 60° C) were tested in the apiary by using them with the solvent or by drying. The data collected on the number of wasps attracted to these extracts showed no attractency at all. However, when the extracts of *V. auraria* were used with the fermented honey and placed in the apiary in jars showed some results which are tabulated as under:

Table 10.

Attractancy of the wasps to the ether extracts (30^0 C) of *V. auraria* mixed with fermented honey in the apiary at Nauni,1997.

Date	Number trapped per day				
	V. auraria	*V. basalis*	*V. cincta*	Total	Bees
25-09-97	0	2	1	3	3
26-09-97	1	0	4	5	5
27-09-97	1	2	2	5	5
28-09-97	2	0	0	2	2
29-09-97	4	3	2	9	4
30-09-97	1	0	3	4	4
Mean±S.E				4.7±0.37	3.8±0.18

* Pooled data for three jars

The data revealed that on an average 4.7±0.37 wasps and 3.8±0.18 bees were trapped per day in the jars. This catch is almost same as in case of fermented honey (Table 8). This may be due to the fermented honey as the extracts alone yielded no results.

4.7 Meat and Fish baits

The data collected on fish and meat baits (Table 11) used in the apiary as attractants for the wasps revealed that 48, 45 and 30, 26 wasps were attracted on 15th and 16th October, respectively. When the experiment was repeated on 20 th and 22 nd October after heavy rains only 12 6 and 6, 4 wasps, respectively, were attracted to these baits. This preliminary study on the attractency of wasps to fish and meat baits revealed that more number of wasps were attracted to fish in comparison to meat.

Table 11.

Attractency of wasps to fish and meat baits in the apiary in October, 1997.

Baits	Wasp species	Number of wasps attracted to petriplates* (per 10 minutes)			
		15-10-97	16-10-97	20-10-97	22-10-97
Fish	*V. auraria*	28	26	9	3
	V. basalis	20	19	3	3
	Total	48	45	12	6
Meat	*V. auraria*	18	13	4	2
	V. basalis	12	13	2	2
	Total	30	26	6	4

CHAPTER 5

DISCUSSION

Experimental results of the investigations carried out on the incidence, damage to bees and control of the predatory wasps in the university apiary at Nauni, Solan are discussed as follows:

5.1 Incidence

5.1.1 Queen visitation

Colonies of the wasps are annual with fertilized queens overwintering in diapausing stage, in the tropics they are cyclic with colonies in all stages of development throughout the year. The cycle of the wasps with annual colonies starts with the appearance of the overwintered queens in spring. From the results on incidence of the predatory wasp queens in 1997, it is inferred that they started visiting the apiary in March and continued till June. During this period the queen visitation per day varied (0 to 2) with no particular trend. Similarly, Sharma (1978) has noticed the first *V. auraria* queen on 23rd March and the last on 15th May, at Oachghat (Nauni) during 1976. This slight variation may be due to the different weather conditions in these years. The result also receives support from the findings of Singh (1962) in India and Donovan (1992) in New Zealand, who observed that the cycle of the wasps begins with the foundation of the new nests in Spring by the queen and all work is done by her until the first batch of the brood emerges and takes over the duties except egg laying.

5.1.2 Workers

5.1.2.1 Initiation and Cessation of the attack

In August,1997 visitation of *V. auraria* started early in the morning at 0545-0616 h and ceased in the evening at 1900-1930 h at the University apiary. The findings of Sharma *et al.* (1985) showed that their activity initiated at 0550 h and stopped at 1800 h at Nagrota Bagwan (Kangra) in the month of October. This early visitation at Kangra may be attributed to the different geographic and climatic conditions.

5.1.2.2 Visitation of *V. auraria*

Data collected on the visitation showed that *V. auraria* workers started visiting the apiary with a low frequency i.e. 10.0±1.41 wasps per day in the apiary during June,1997 (Table 3), it gradually increased to maximum during September, then it declined during October and was negligible in December at the university apiary in 1997. Earlier, Sharma (1978) had also noticed the low incidence (3-5 wasps per day) at Oachghat (Nauni) apiary during June. The peak attack of wasps was in the months of September which declined to minimum in the month of December at the same place during 1976. The peak period of the wasp incidence during August-September also recieves support from the findings of other investigators in different parts of India (Singh, 1962; Kshirsagar and Mahindre, 1975), in Egypt (Wafa, 1956) and in New Zealand (Donovan, 1992). The incidence of *V. orientalis* was also reported to begin in August, reaching at its peak during September-October and declined to negligible in November by Ibrahim and Mazeed, (1967) in Pakistan and Mellor, (1928) in Egypt is similar to the cycle of *V. auraria* observed at the university apiary at Nauni.

5.1.2.3 Visitation of *V. basalis*

Data on the incidence in 1997, showed that *V. basalis* started its activity in the third week of August and continued to visit upto second week of November. The duration of its visitation was next to *V. auraria* in the apiary at Nauni. These

observations are in conformity with the findings of Sharma, (1978) who observed their visitation from August to November,1976 .

5.1.2.4 Visitation of *V. cincta*

Data collected on the visitation of *V. cincta* reveals that this wasp appeared in the month of September and continued to visit till the second week of November, 1997. According to findings of Sharma (1978) its visitation started earlier (first week of August) but ended in the same month during 1976 with almost same duration of visitation. However, Subbiah and Mahadevan, (1957) noticed that the visitation of *V. cincta* in the apiary was from June to December at Coimbatore which was of longer duration. This difference could be attributed to the favorable climate and ecological conditions of this region.

5.1.2.5 Visitation of *V. magnifica*

During 1996, no wasps of *V. magnifica* attacked the apiary of *A. mellifera*. However, three wasps of the species were encountered from October to November 1997. Therefore, complete comparision could not be made about the appearance, disappearance and peak abundance of this wasp because little work has been done on its seasonal incidence.

Out of the above four mentioned species of the predatory wasps, *V. auraria* and *V. magnifica* are considered to be most destructive to *A. mellifera* colonies. However, during the period of our investigations *V. auraria* posed a serious threat to the honeybees as it visited regularly from June to December and in addition ti it the lifting capacity was very high during peak activity hours in the apiary at Nauni. None of the wasp species were observed in the apairy from December to Feburary. The absence

of wasps in the winter months is a routine behavior pattern of annual colonies with overwintering queens have already been studied by Van-der-Vecht (1957), Donovan (1992) and Akre and Mayer (1994).

5.2 Relation to rainfall and temperature(s)

The incidence of the predatory wasps with regard to initiation and severity of the attack is directly related to the temperature and rainfall in March-May This is clearly indicated by the graphs plotted for temperature and rainfall (2 week moving average method) in Figure 4. Lower minimum temperature and high rainfall in March-May tend to delay the appearance of queens or prolonged the overwintering period, which is evident from the delayed incidence in 1997. This may be due to the fact that the meteorological conditions during these months prolonged the hibernation of overwintering queens. Conversely, dry and warm weather during March to May tends to favour early appearance of overwintered queens, their survival and establishment of the nests as was indicated by the early incidence during 1996 (Plate II). The findings of Long *et al.* (1979); Akre and Reed (1981) and Mac Donald *et al.*(1976) are also in concurrence to our results. However, rainfall and temperature(s) alone does not account for the incidence and severity of the wasps, there might be some additional factors operating.

5.3 Extent of Damage

The data collected on the extent of damage (Table 4) indicated that *V. auraria* caused immense damage to the honeybee colonies in the apiary. They lifted on an average 96.3±5.77 bees per 30 minutes during the peak activity hours in the month of September. Thus, in the whole day they could lift away upto 700 bees from the apiary. The damage to the bees is directly related to the frequency of wasps visiting the apiary. The damaging capacity of *V. auraria* is concurrent with the findings of Sharma *et al.*,(1985), who observed that in October, *V. auraria* could lift away 600-900 bees in

a day from the apiary at Nagrota. Sharma (1979) worked out the damage by *V. auraria* in September to be 62.21 bees per day in *A. mellifera* apiary at Saproon in 1976.

V. basalis and *V. cincta* were rarely observed to lift the active worker bees from the hives during the period of our observations. On the contrary, Sharma (1978) has reported *V. basalis* and *V. cincta* to cause some damage to the worker bees during 1976.

5.4 Control

Results obtained from the experiments conducted to control the predatory wasps in the university apiary of *A. mellifera* are discussed as follows:

5.4.1 Fermented honey

Experiments conducted on the use of fermented honey to kill the predatory wasps revealed that a total of 5.0±0.45 wasps and 2.7±0.12 bees were attracted and killed in the jars per day in the month of September (Table 6). The catch was very low in comparison to the frequency of wasps visiting the apiary i.e. 266 wasps per day. However, Higo (1983) used fermented honey in 12 traps placed in the 10 apiaries from mid August - November in Japan and obtained good results by trapping over 10,000 *V. xanthoptera*, 100 *V. mandarina* and 8 *V. insularis* workers in them. This high attraction of *V. xanthoptera* and other species of the wasps could probably be due to different environmental and ecological conditions of these two countries.

5.4.2 Honey syrup

Present studies showed that the total number of wasps killed by attracting and trapping wasps in jars containing honey syrup was 7.1±0.23 wasps per day in September,1997. Moreover, 9.1±0.16 bees per day were also caught in these

jars. In comparison to the frequency of wasps visiting the apiary during this period the catch in the jars was very low. However, Muzaffer and Ahmed (1986) recorded some degree of control of predatory wasps by using plastic jars containing 50% sucrose solution kept on top of the hives in the apiary in Pakistan. Lower catch in our experiments may possibly be due to the specificity in behaviour of these social insects i.e., the preference of the wasps for bees did not change as they mainly visited the apiary for bees as a supplement of proteins to feed the developing brood.

5.4.3 Wire mesh cage

Results obtained on the use of wire cage (2.5 **X** 2.5 cm) fixed at the hive entrance during September-October,1997 in order to create hindrance for *V. auraria* to lift bees indicated that comparative lifting from the modified hive (with cage) and the control hive was non-significant because it easily adapted to the modification and started lifting bees just outside the cages. Similar results are reported by Sharma (1978) with a simple cage (12.5 cm **X** 0.5 cm) at the alighting board which could not protect the bees from the attack of *V. auraria* at Oachghat, Nauni in 1976.

5.4.4 Bird scare ribbons

The data collected on the use of bird scare ribbons as a control measure showed non significant difference in the number of bees lifted by the predatory wasps from the hives with ribbons and without the ribbons (Table 9). This is attributed to the fact that the activity of the bees was hindered by the movement of the ribbons whereas the wasps were not affected and continued to visit as if no modification had been made.

5.4.5 Chemical extracts

Experiments conducted on the chemical extracts of *V. auraria* (different body parts and whole) and bees were not at all effective in attracting even a single wasps of this species to the petriplates (dry) or the jars containing the extracts

(with the solvent). However, when these extracts were used in combination with fermented honey, 4.67±0.37 wasps were caught (Table 10). This was purely due to the fermented honey as these extracts alone did not attract even a single wasp. The studies of Mizoue (1983) in Japan showed that the ether extracts of the bodies of the workers of *V. mandarina* attracted the worker wasps of the species in October and November. He further studied that the acidified fraction of the extract was particularly attractive. This may be due to the presence of trail marking pheromones in these wasps.

5.4.6 Meat and Fish

Meat and fish baits appeared to be more promising as compared to the other methods for the control of the predatory wasps as more number of wasps were attracted to these baits. The order of attractency for this bait was: fish > meat. This study need to be experimented upon for concrete results as similar results were not obtained when the experiment was repeated on 22nd October after heavy rains (16th to 18th October, 1997).

CHAPTER 6

SUMMARY AND CONCLUSION

Summary

Results obtained from the studies on the incidence of the predatory wasps of honey bees and their control are summarized below:

1. Four species of the genus V*espa* viz., *V. auraria, V. basalis, V. cincta* and *V. magnifica* were found to visit the apiary of *A. mellifera* at Nauni.

2. In the year 1997, the visitation of first *V. auraria* queen was recorded on 10th March it continued upto 15th June in the apiary.

3. The incidence of *V. auraria* workers in the apiary was low, 64.4±4.05 wasps per day during the second week of June, which rose to maximum in the first week of September (282.4±9.31 wasps per day) and declined to minimum in the third week of December,1996. Similarly, during 1997 its attack initiated in June with 10.0±1.41 wasps per day which rose to maximum (245.7±6.46 wasps) in September and declined to minimum in December (8.0±1.41 wasps).

4. The incidence of the wasps is directly related to the minimum temperature and rainfall in March-April and April-May, respectively. Lower temperature and high rainfall in the months during the emergence and

establishment of the wasp queens tend to delay the attack of the wasps in the ensuing season.

5. Visitation of *V. basalis* started in the second week of August and continued till December with a peak of 29.5±4.92 wasps per day in the month of November, 1997. *V. cincta* was observed in apiary during September with a maximum of 7.0±0.93 wasps per day in the month of October. However, only three *V. magnifica* workers were encountered during 1997.

6. *V. auraria* posed a serious threat to *A. mellifera* as caused maximum damage to them. It lifted away 82.3±6.04 to 96.3±5.77 bees from the apiary in the month of September in 30 minutes at peak activity hours.

7. Trapping and killing of the wasps in jars containing fermented honey and honey syrup revealed that the average catch in the jars was 5.0±0.45 and 7.1±0.23 wasps per day respectively, in *A. mellifera* apiary in 1997.

8. Studies conducted on the use of wire mesh cage at the hive entrance and the use of bird scare ribbons for the control of the predatory wasps by creating hinderance showed non significant results in terms of number of bees lifted from the modified hives and the control hives.

9. The experiments conducted on use of extracts of wasps and bees in different solvents (acetone, hexane and diethyl ether) and at different temperature(s) (0, 10, 30, 50, and 60° C) did not show any attractancy for the wasps.

10. Fish was found to be more attractive bait followed by meat to attract the predatory wasps.

Conclusion

V. aurarua, queens were the first visitor in the apiary, they initiated predating on honeybees from the first week of March. They continued visiting the apiary and predating till the middle of June. The population of worker wasp appeard in the apiary during the second week of June. This was the period when fecundated queens were not observed visiting the apiary. The workers of *V. auraria* continued predating on honeybees till December with their maximum incidence in September. On the other hand , *V. basalis* showed its appearance in the month of August while *V.* cincta appeared in September with their maximum incidence in October-November and September respectively. During the present studies three workers of *V. magnifica*, a highly potent predator, visited the apiary.

Control of the wasps by flapping is not an effective method to check their incidence and population growth but it is an important protective measure to save the colonies from their ravages. The use of wire mesh, bird scare ribbons in front of the bee colonies, fermented honey and honey syrup in baiting jars did not yield significant results in comparision to the total number of wasps visiting the apiary. The extracts from the bodies of the wasps and bees in different solvents were totally ineffective. Preliminary studies on baiting the wasps with fish and meat showed promising results which further need to be experimented upon.

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APPENDIX

Data on maximum temperature, minimum temperatute and rainfall which prevaled during January-May in 1996 and 1997.

Month	Week(s)	Maximum tempearture °C		Minimum temperature °C		Rainfall mm	
		1996	1997	1996	1997	1996	1997
January	1	17.7	19.7	2.9	3.1	16.0	0
	2	16.9	18.7	3.7	2.0	2.8	0
	3	13.3	17.6	3.1	1.9	65.4	1.8
	4	16.1	14.3	2.9	0.7	12.4	49.0
Feburary	1	20.0	17.4	4.2	1.7	0	3.2
	2	18.4	15.1	6.3	2.1	12.6	13.0
	3	19.5	17.9	5.0	3.9	19.4	1.4
	4	18.5	18.7	6.1	2.7	25.2	0
March	1	20.6	23.7	12.3	9.5	60.4	0.6
	2	23.3	22.5	11.0	10.0	11.2	11.4
	3	19.7	20.8	8.7	8.7	65.2	7.4
	4	24.7	22.8	12.3	9.0	5.0	18.0
April	1	25.4	19.1	11.7	9.3	1.8	61.0
	2	26.1	23.9	13.0	12.1	0	37.6
	3	28.9	25.3	16.1	13.5	1.0	13.4
	4	21.1	28.5	15.9	14.7	1.8	0
May	1	31.4	26.7	15.5	14.8	4.2	23.4
	2	31.5	26.1	15.4	14.6	7.0	36.6
	3	29.3	29.1	14.4	16.1	8.6	0
	4	30.5	31.5	16.0	16.6	0	7.8

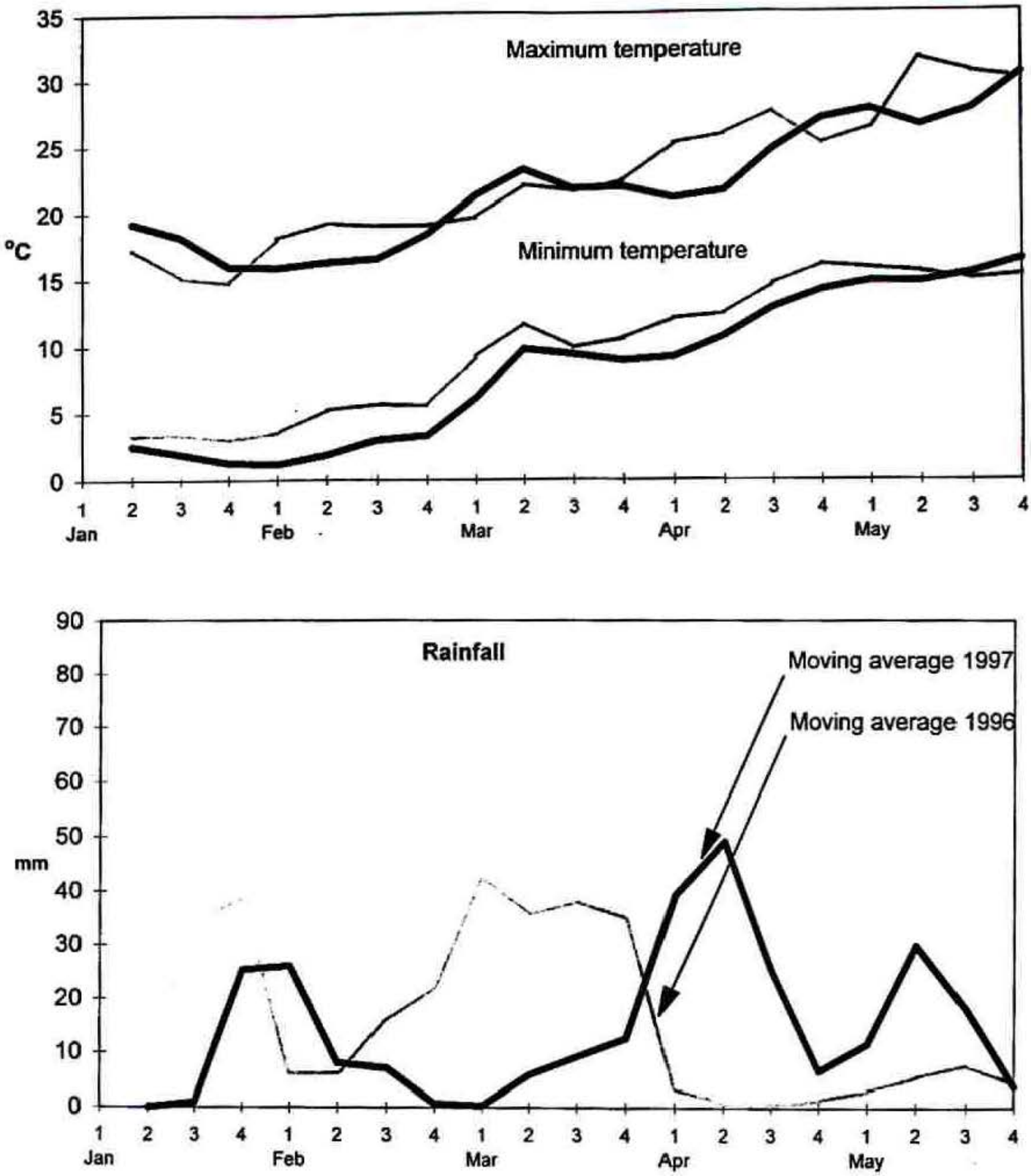

Figure 4. Moving averages (2 week) for maximum temperature, minimum temperature and rainfall in 1996 and 1997.

CURRICULUM VITAE

Name	Ajay Kumar
Father's Name	Sh. PC Kundle
Date of birth	27-11-1974
Age at the time of submission	23 years
Sex	Male
Martial status	Unmarried
Nationality	Indian

Educational qualifications

Exam passed	Division	Board/university	Year
10+2	First	CBSE	1992
B.Sc.	First	HPU-Shimla	1995

Weather sponsored by some State/Central Govt./Univ./SAARC NA

Scholarship/stipend/fellowship/any other financial assistance received during

i)	10+2	NA
ii)	B.Sc.	NA
iii)	M.Sc.	University stipend

DEPARTMENT OF ENTOMOLOGY AND APICULTURE

1	**Title of thesis**	**Studies on the predatory wasps of honeybees and their control**
2	**Name of the Student**	**Ajay Kumar**
3	**Admission number**	**H-95-55-M**
4	**Major Advisor**	**Dr. BS Rana,** Entomologist
5	**Major field**	**Apiculture**
6	**Minor field(s)**	**i) Plant Pathology** **ii) Floriculture**
7	**Degree awarded**	**M.Sc. Entomology & Apiculture**
8	**Year of award of degree**	**1998**
9	**Total pages of thesis**	**41+vi**
10	**Number of words in abstract**	**207**

ABSTRACT

Among different predatory wasp species (*Vespa auraria, V. magnifica, V. basalis* and *V. cincta*) encountered during the course of study in the University apiary at Nauni (Solan), it was found that the frequency and duration of the attack of *V. auraria* was maximum, followed by *V. basalis, V. cincta* and *V. magnifica*. Queens of *V. auraria* were the first visitors in the apiary, they initiated predating on honeybees in March and continued till the middle of June. Among different species, *V. auraria* posed a serious threat to the beekeeping industry. Studies on extent of damage showed that this wasp's predation on honeybees was very high and caused immense losses to the bees. The incidence of the wasps is directly related to the metrological factors prevalent during January to May. Evaluation of the control methods revealed that flapping is not an effective method, though it is a good protective measure to save the bee colonies from the wasp ravages. The use of wire mesh, bird scare ribbons at/infront of the bee hives, fermented honey and honey syrup in the baiting jars did not yield significant results. The extracts of *V. auraria* and bees were totally ineffective. Meat and fish baits showed promising results which need to be further experimented upon.

Signature of Major Advisor

Signature of the student

Professor and Head
Department of Entomology and Apiculture
Dr. YS Parmar University of Horticulture
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Y... SOLAN
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