DEFENSIVE BEHAVIOUR OF *Apis cerana* F. AGAINST PREDATORY WASPS

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Summary

Defensive behaviour of *Apis cerana* F. was studied against predatory wasps *Vespa velutina* and *Vespa magnifica*. The honeybee *Apis cerana* showed a well organized defense and killed more number of predatory wasps by exhibiting well organized balling behaviour as compared to *Apis mellifera* L. The bee mortality was higher when fewer wasps visited the apiary due to an unorganized defence. However, when the intensity of attack was severe, fewer bees and more wasps were killed due to an organized defense.

Keywords: *A. cerana*, *A. mellifera*, foraging, defense, balling temperature, hornet, *Vespa velutina*.

INTRODUCTION

Wasps are serious enemies of honeybees and cause considerable damage. A persistent attack by wasps weakens the colony and most often the colonies either perish or abscond (Singh 1972, Sharma and Raj 1988, Shah and Shah 1991). Furthermore, a wasp attack most often coincides with floral dearth periods when nectar and pollen sources are insufficient. The wasps *Vespa velutina* and *V. magnifica* are serious predators of honeybees in Jammu and Kashmir. On emergence from its winter period of dormancy in spring, the queen hornet visits apiaries in search of food for herself and the larvae and scrape wood for use as nest building material. Initially, a small cup-shaped nest is constructed by the queen hornet, often under the eaves and roofs of houses and branches of tall trees. After the first generation of brood has been reared, the nest size and colony strength increases throughout the summer, reaching a peak in autumn. It is this period (July to October) that demand for food is greatest and bee colonies are at greater risk. A number of methods are available to control the wasps, which include the killing of wasps by flapping, poisoning by different baits, trapping, killing of queens, destruction of their nests by burning or poisoning of nests etc., but these methods are either not cost effective or have environmental problems. As a rule of nature, each living organism has developed one or more strategies to defend against their enemies (Okada 1984, Matsuura 1973, 1988). In earlier studies, Ahmad et al. (1985) and Muzaffar and Ahmad (1986) reported that wasps inflicted heavier damage to *Apis mellifera* colonies compared to *Apis cerana* as the latter species defended strongly against their attacks. Ono et al. (1987) and Ichino and Okada (1994) reported that workers of *Apis cerana japonica* showed a distinct balling reaction against workers of the predatory hornet *Vespa simillima xanthoptera* killing the hornets by heat and suffocation generated inside the ball. It was therefore felt desirable to evaluate the strategies, if any, adopted by the local honey bee *Apis cerana* and the introduced bee *A. mellifera* against their enemies.

MATERIALS AND METHODS

From August to October when the hornet population is the highest, two apiaries were studied – one *Apis cerana* and one *Apis mellifera*, each consisting of 25 colonies. However, for experimental trials, two units of 10 colonies of each honey bee species were marked, each with a uniform strength of 10 frames. The observations were made for 22 different days on the marked colonies from August to October on the number of wasps visiting the apiary and their behavioural interactions with bees of both *Apis cerana* and *Apis mellifera*. Observations were made simultaneously by two observers (one in each apiary) for two hours during the morning, midday and afternoon on different days. Predatory strategies adopted by the wasps and counter attack strategies adopted by the bees were also recorded. The temperature inside the ball was measured with the help of an LCD Portable Multi-Stem Thermometer with an external sensing probe. The recorded data were analyzed for correlations and a paired t- test following Sokal and Rholf (1981).

RESULTS

The data presented in Table 1 show that the number of wasps visiting the apiary ranged from a minimum of 11 to 35 wasps per 2 hours with an average of 27.18±6.32 wasps/2h from August to October. The number of bees captured by wasps also varied with the intensity of the attack. The number of bees captured by wasps ranged between 3 to 5 with an average of 4.27±0.70 bees/2h. The number of wasps balled and killed by bees varied between 0 to 6 with an average of 3.41±1.40 wasps/2h. The data reveals that with the increase in intensity of attack of hornets, there was a corresponding increase in the balling reaction of bees and the number of wasps killed ($r = 0.840$, $p < 0.01$, $n = 22$) and there was lower mortality of bees ($r = 0.053$ ns, $n = 22$) because of the organized defense of the colony. Bees were found to deploy 86 to 240 guard bees for a ball formation depending upon the intensity of the attack. But with a casual attack by hornets, bees were caught unaware and suffered more casualties. It was interesting to find that highest percentage of bees were killed (27.27) when there were only 11 visits of wasps/2h, but the percentage mortality of bees was much lower (10 – 26) when the intensity of wasp visits was between 18 to 35 visits/2h (10 – 26%). On the other hand, the percentage of wasps balled and killed was much higher when the intensity of the wasp attack was higher. No wasp was captured or killed when the frequency of the wasp attack was 11/2h; however, 7.69 to 18.51% wasps were killed when the intensity of the attack was between 18 to 35 visits/2h.

It was interesting to note that in the case of *Apis cerana* bees, when hornets approached the hive, the guards deployed at the entrance sit at and around the hive entrance and shake their bodies from side to side; (this behaviour is referred to as 'shimmering' behaviour, Koeniger and Fuchs 1973) started shimmering movements in front of the hive on the bottom board, thereby showing awareness of the hornet and frightening the latter. This action was sufficient to drive away the wasps and keep them away from the hive. However, if a wasp persisted its attempt to attack and continued hovering in front of the hive, the guard bees were found to become incensed; they shimmered more violently, which repelled the hornet. At the same time, a couple of guard bees dart towards the hornet and pull it down. Instantly, other bees followed and within 12 – 15 seconds the ball engulfing the wasp was complete. They were found to seize, bite, pull, hold and sting it. Initially, a loose ball is formed around the attacker, but gradually some bees leave the ball and the remaining bees

Table 1

Number of wasps visiting apiary and their encounters with the indigenous honeybee *Apis cerana* during August to October, 2004.

Date of observation	Number of wasps observed	Number of wasps returning with bees	Bees killed by wasps (%)	Wasps killed	Wasps killed (%)	Number of bees involved in balling	Balling period (min)	Temperature inside the ball (°C)	No. of bees killed in the process of balling
August									
3	25	5.00	20.00	4.00	16.00	160.00	52.50	45.00	1.00
7	18	4.00	22.22	2.00	11.09	182.00	50.50	46.00	0.00
10	27	4.00	14.71	3.00	11.09	200.00	46.00	46.20	0.00
12	21	4.00	19.04	2.00	9.52	86.00	65.00	45.00	0.00
15	28	3.00	10.07	4.00	14.28	116.00	58.00	46.40	1.00
17	29	5.00	17.27	3.00	10.03	170.00	66.00	46.40	0.00
21	35	4.00	11.42	5.00	14.28	194.00	72.00	45.80	2.00
24	33	5.00	15.15	4.00	12.12	164.00	67.00	45.60	0.00
27	19	5.00	26.31	2.00	10.05	220.00	48.00	46.60	0.00
30	11	3.00	27.27	0.00	0.00	0.00	0.00	0.00	0.00
September									
5	28	5.00	17.85	4.00	14.28	192.00	44.00	46.10	0.00
8	32	4.00	12.50	4.00	12.50	196.00	49.00	45.60	0.00
10	22	5.00	22.72	3.00	13.63	152.00	46.00	46.00	2.00
12	26	4.00	15.38	2.00	7.69	200.00	56.00	45.20	0.00
16	31	4.00	12.90	4.00	12.90	155.00	74.00	45.70	0.00
20	33	3.00	9.09	6.00	18.18	160.00	64.00	45.40	0.00
22	27	5.00	18.51	5.00	18.51	186.00	74.00	46.00	1.00
26	22	5.00	22.72	2.00	9.09	212.00	62.00	46.00	0.00
29	28	4.00	14.28	3.00	10.07	240.00	45.00	46.10	0.00
30	35	4.00	11.42	5.00	14.28	198.00	56.00	46.80	0.00
October									
2	33	4.00	12.12	3.00	9.09	112.00	76.00	46.60	3.00
4	35	5.00	14.28	5.00	14.28	194.00	58.00	45.80	0.00
Mean±SD	27.18±6.32	4.27±0.70	16.6±5.16	3.41± 1.40	11.9±3.93	167.7± 52.3	55.8± 16.14	43.8± 9.80	0.45± 0.85

form a tight ball and stay in the ball ranging from 44 to 76 minutes with an average of 58.52±10.49 min. A few bees (between 5 and 10) may remain alert near the ball to repel a possible attack by another hornet. The number of bees in the ball ranged between 86 to 240 with an average of 175.67±37.35 bees per ball. If the number of bees was higher, the time of balling was shorter ($r = -0.451$, $p < 0.005$ [$n = 22$]). It was interesting to note that after 25 to 30 min of balling, the number of bees involved in the process declined and 30 to 40 percent of the bees continued with the ball till the wasp was severely mutilated and rendered completely motionless. The tem-

Table 2

Number of dead wasps collected from apiaries of *Apis cerana* and *Apis mellifera* from August to October, 2004.

Date of observation	Bee species	
	Apis cerana	*Apis mellifera*
August		
3	12.00	2.00
7	10.00	1.00
10	13.00	0.00
12	12.00	0.00
15	8.00	2.00
17	11.00	2.00
21	12.00	3.00
24	11.00	0.00
27	10.00	0.00
30	10.00	1.00
September		
5	8.00	2.00
8	6.00	0.00
10	12.00	0.00
12	15.00	0.00
16	11.00	1.00
20	12.00	1.00
22	13.00	0.00
26	10.00	0.00
29	6.00	1.00
30	8.00	1.00
October		
2	4.00	2.00
4	6.00	2.00
Mean±SD	27.18±6.32	16.69±5.16

perature inside the ball was found to rise between 45 to 46.8°C with an average temperature of 45.19±0.51°C. However, the temperature inside the ball was not much affected by the number of bees ($r = 0.22$, ns, $n = 22$). The wasp was found to die due to heat and suffocation, as was evident by the curled and mutilated wings of the wasp and none of the wasps survived once engulfed in the ball. However, one or two bees occasionally died in the process of balling.

The defensive behaviour of *Apis mellifera*, on the other hand, was not well organized and wasps inflicted heavy losses on their colonies. During hornet attacks on *A. mellifera* colonies, up to 150 workers form a close cluster at and around the hive entrance. When a hornet approaches the cluster, one or two bees may leave the cluster and walk rather aggressively towards the hornet, but this behaviour does not repel the hornet, which seizes one of the bees and flies off with it. Guard bees seldom attack the hornets and appear incapable of seizing and holding a captured hornet firmly enough for it to be killed. The bees, in an attempt to capture the wasp, chased it in low numbers and were killed in the process. Unlike *Apis cerana*, they do not attack en masse and suffered more casualties. The number of dead wasps collected from the apiary of both *A. cerana* and *A. mellifera* (Table 2) revealed that number of wasps killed by latter species of bee was much lower than the former. *Apis cerana* killed 4 to 15 wasps during different days with an average of 10.00±2.77/day as compared to *A. mellifera* where this number ranged from 0 to 3 with an average of 0.95±0.95/day. The differences were found to be highly statistically significantly (paired t test $T = 14.45$, $P < 0.00$, $df = 25$).

Wasps were also found to adopt counter attack strategies to maximize gains and minimize losses in the following ways:

a) they preferred *Apis mellifera* bees as they met very little resistance due to less-organized defense. In the case of weak colonies, they could enter the hives and eat the bees, brood, nectar stores etc. – whatever was in their way.
b) Some of the wasps continued flying around the back of the hive in order to prey on individual bees, without any apparent danger from the guard bees. By this method, they were able to prey on a large number of bees with minimum risk.
c) They captured the bees whilst in flight and or foraging on flowers.
d) Some hornets in groups of 3 – 4 remained hovering near the hive entrance to distract the attention of the bees; when the bees chased a lone wasp, the other wasps could ambush the bees.
e) Some hornets remained hovering in one spot and pounced on incoming bees laden with nectar or pollen.

On the bee side, their defensive strategy is highly cost-effective in terms of energy involved, loss of time and collection of stores. In a ball, an average of 175.67± ±37.35 bees are involved and the balling continues for an average of 58.52±10.49 min which results in a loss of more than 165 bee hours/ball/day. Additionally, if on an average 2-3 balls are formed per day per colony, the losses could be much higher. Evidently, in addition to the defensive strategy of the bees, some control measures such as using traps, baiting of wasps, physical killing by flapping, killing of queens and destruction of wasp nests could help the colony to collect more nectar and pollen resources.

DISCUSSION

The studies have demonstrated that *A. cerana* have a well-organized defense against predatory hornets compared to

A. mellfera. In earlier studies, Ono et al. (1987, 1995) reported an unusual defensive behaviour in the Japanese honey bee (*Apis cerana japonica*) against attack from predatory hornets. The hornet *Vespa mandarina japonica* has evolved a group predation strategy against other social bees and wasps. A scout hornet first marks the location of the site with a pheromone and other hornets will later attack the prey en masse. However, *A. cerana japonica* appears to have co-evolved to detect this marking behavior and may attack the lone scent-marking hornet en masse themselves. When this occurs, four or five hundred bees will form a tight ball around the hornet, a behaviour the authors term "balling" The large number of bees and the compactness of the ball means that the internal temperature of the ball, i.e. the hornet's "ambient" temperature, is raised sufficiently high to kill the hornet but not the bees. The lethal temperature for the bees is 48 – 50°C whereas for the hornet it is only 44 – 46°C. In effect, the ball is used to form an oven to cook the hornet. Ono et al. (1995) also suggest that an alarm pheromone, isoamyl acetate, whose evaporation is aided by the high temperatures, may act as a recruitment signal for other bees to join the structure. This species of bee reacts in a similar manner to attacks from a solitary hunting hornet, *V. simillima xanthoptera* and although the balls only consist of around 180 – 300 bees, the effect is the same. Susan (2005) reported that at least two species of honeybees, the native *Apis cerana* and the introduced European honeybee, *Apis mellifera*, engulf a wasp in a living ball of defenders and heat the predator to death. The present findings, however, differ from Ono et al. (1987, 1995) who reported that Japanese honey bees (*Apis cerana japonica*) do not sting a captured wasp, but it is rather the temperature within the ball that kills the hornet. The present study shows that the indigenous honey bee *Apis cerana*, in addition to thermal defense, try to sting repeatedly at the junction between thorax and abdomen immediately after capturing a hornet. As soon as the hornet was dead, the bees gradually dispersed from the ball. An occasional bee may then try to remove the corpse, but is usually unsuccessful. The native Asian bees were found to have better heat-balling tactics than the European imports do. The native bees gather one-and-a-half times as many individuals in their swarms as the European bees do. In earlier studies, Sakagami (1960) and Butler (1962) have also reported that *Apis mellifera* bees are heavy and slow in movement and fall easy prey to enemies. A new study of heat balling has described a margin of safety for the defending bees. Ken et al. (2005) report that the native bees use heat-balling techniques that the European bees lack. That makes sense, the researchers say, since the Asian bees have long shared their range with the attacker wasp *Vespa velutina*, but the European bees became widespread in Asia only some 50 years ago and so have had much less time to adapt to this wasp. The defensive abilities of *Apis cerana* and *Apis mellifera* honeybee colonies (actively balling the wasps) was found to significantly reduce the foraging activity with increased wasp attack time. They further found that core temperatures in a ball around a live wasp of *A. cerana* were significantly higher than those of *A. mellifera*. The lethal thermal limits for *V. velutina*, *A. cerana* and *A. mellifera* were significantly different, so that both species of honeybees have a thermal safety factor in heat-killing such wasp predators. The Japanese honeybee (*Apis cerana japonica*) has evolved an ingenious method of defending against the much larger predator. When a hornet scout locates a Japanese honeybee hive and approaches the nest, the scout will emit specific pheromonal hunting signals. When the honeybees detect these pheromones, a hundred or so honeybees will gather near the entrance of the nest, apparently to draw the hornet further into the hive. As the hornet enters the nest, a large mob of about five hundred honeybees surround the hornet, completely covering it and preventing it from moving, and begin quickly vibrating their flight muscles. This has the effect of raising the temperature of the honeybee mass to 47°C. Though the honeybees can tolerate such a temperature, it is fatal to the intruder, which can handle a maximum temperature of about 45°C, and is effectively baked to death by the large mass of vibrating bees. The wasps died at 45.7°C, but the Asian honeybees survived temperatures up to 50.7°C and the European bees survived up to 51.8°C (Susan 2005).

CONCLUSIONS

The studies show that *Apis cerana* has a well-organized defence strategy against predatory wasps compared to *Apis mellifera*. Evidently, proper management of wasps through regular care and other control methods such as physical killing of wasps, baiting of wasps with lures, destruction of their nests and destruction of queens during early spring coupled with a well-organized defence could lead to better honeybee colonies with improved honey production and pollination. The study further reveals that *Apis mellifera* whose defensive behavior is not as effective as *A. mellifera*, needs particular attention and care to save the colonies from the onslaught of predatory wasps.

REFERENCES

Ahmad R., Muzaffar N., Munawar M.S. (1985)– Studies on biological control of hornet predators of honeybees in Pakistan. In: *Proc. XXX Intl. Cong*., Apic, Nagoya, Japan.

Butler, C.G.(1962)– The World of Honeybee. 2nd Edition, London.

Ichino H and Okada I. (1994)– Japanese honey bees living in hornet nest. *Honeybee Science.* 15(3): 123 – 124.

Ken T. Hepburn, H. R., Radloff S. E., Yusheng Yu. Yiqiu, Liu Danyin Z ., Neumann P. (2005)- Heat-balling wasps by honeybees. *Naturwissenschaften* 92(10): 492 – 495.

Koeniger N., Fuchs S. (1973)– Sound production as colony defence in. *Apis cerana*. Proc Int IUSSI Congr 7: 199 – 204.

Matsuura M., Sakagami S.F. (1973)– A bionomic sketch of the giant hornet, *Vespa mandarinia*, a serious pest for Japanese apiculture. *Journal of the Faculty of Science, Hokkaido University, Series VI, Zoology.* 19(1): 125 – 162.

Matsuura M. (1988)– Ecological study on Vespine wasps (Hymenoptera: Vespidae) attacking honeybee colonies. I. Seasonal changes in the frequency of visits to apiaries by vespine wasps and damage inflicted, especially in the absence of artificial protection. *Applied Entomology and Zoology* 23(4): 428 – 440.

Muzaffar N., Ahmad R. (1986)– Studies on hornets attacking honeybees in Pakistan. Pakistan. *J. Agric. Res.*, 7(1) :59 – 63.

Okada I. (1984)– Aggressive behaviour of honeybees against hornets in Japan. *Honeybee Science.* 5(3): 105 – 112.

Ono M., I. Okada., M. Sasaki (1987)– Heat production by balling in the Japanese honeybee, *Apis cerana japonica* as a defensive behavior against the hornet, *Vespa simillima xanthoptera* (Hymenoptera: Vespidae). *Experientia.* 43: 1031 – 1032.

Ono M., Igarashi T., Ohno E., Sasaki M. (1995)– Unusual thermal defense by a honeybee against mass attack by hornets. *Nature*. 377: 334 – 336.

Sakagami S.F. (1960)– Preliminary report on the specific difference behaviour and the other ecological characters between European and Japanese honeybee. *Acta Hymenopterologica*. 1: 171 – 198.

Shah F.A., Shah T.A. (1991)– *Vespa velutina*, a serious predator of honeybees in Kashmir. *Bee World*. 72(4): 161 – 164.

Sharma O.P., Raj D. (1988)– Ecological studies on predatory wasps attacking Italian honeybee, *Apis mellifera* L. in Kangra Shivaliks. *Indian Journal of Ecology.* 15: 168 – 171.

Singh G. (1972)– Defensive behaviour of *Apis cerana* F. (Hill strain) against predatory hornets in Kashmir. *Indian Bee Journal.* 34: 65 – 69.

Sokal R.R., Rholf F.J. (1981)– *Biometry* (2nd Edition) WH Freeman & Co; San Francisco.

Susan M. (2005)– Balls of fire: Bees carefully cook invaders to death. *Science News Science News*, Vol. 168(13): p. 197.

ZACHOWANIA OBRONNE *Apis cerana* F. WOBEC OS DRAPIEŻNYCH

A b r o l D . P .

S t r e s z c z e n i e

Badano zachowania obronne *Apis cerana* F. wobec os drapieżnych *Vespa velutina* i *Vespa magnifica*. Pszczoła indyjska *Apis cerana* wykazała dobrze zorganizowaną obronę i jej robotnice zabiły większą liczbę os drapieżnych dzięki dobrze zorganizowanemu okłębianiu w porównaniu z *Apis mellifera* L. Brak zorganizowanej obrony przy niewielkiej liczbie os odwiedzających pasiekę powodował zwiększoną śmiertelności pszczół. Jednak przy dużej intensywności ataku, zorganizowana obrona powodowała wzrost liczby zabitych os i spadek liczby zabitych pszczół.

Słowa kluczowe: *A. cerana*, *A. mellifera*, poszukiwanie pokarmu, obrona, temperatura kłębu, szerszeń, *Vespa velutina*.