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Comparative Study of *Apis cerena* and *Apis mellifera*

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ABSTRACT

This paper presents a comparative analysis of the two most important honeybees found worldwide, namely, *Apis cerana* (Asian honeybee) and *Apis mellifera* (European honeybee). Both species are popular for their high-quality honey production and as effective pollinators. A. cerana is known for its hardiness, disease resistance, and ability to tolerate a wide range of temperatures. Additionally, *A. cerana* is smaller in size than *A. mellifera* and exhibits a shyer nature. Both species have similar life cycles, but *A. cerana* demonstrates greater hygiene awareness and is more capable of defending itself against potential threats or disturbances. This paper highlights the importance of understanding the unique characteristics of these two species, which can help inform management practices for beekeepers and aid in conservation efforts for these vital pollinators.

INTRODUCTION

Honeybees (Hymenoptera: Apidae), which belong to the genus Apis, are among the most well-known flying insects found in terrestrial habitats (Koetz, 2013). There are nine currently recognized Apis honeybee species worldwide, eight of which are native to Asia. *Apis mellifera* is the only Apis honeybee species outside of Asia (Koetz, 2013). Of the nine species of Apis, only A. mellifera (the European or Western honeybee) and *A. cerana* (the Asian or Eastern honeybee) have been domesticated for a long time, and are of major commercial importance. Most of these species are limited within tropical and montane zones in Southeast and South Asia, but the two species have far broader ranges. *A. cerana* occurs as far north as Japan and into the Middle East. European honeybee *A. mellifera*, the most representative and well-known honey bee, is native to Europe, Africa, and most of Asia, but it has been introduced into the Americas and Oceania, where feral populations can be found (Breed, 2010).

Due to their different ecological environment, they have different behavioral and physiological characteristics. Compared to *A. mellifera*, *A. cerana* has several distinguishing behavioral traits. It can easily adapt to extreme weather conditions and has long flight duration, effective grooming and hygienic behaviors, and cooperative group-level defenses. A well-known behavior of *A. cerana* is aggregation when a colony is exposed to dangers like predators or intruders. In such situations, guard bees produce alarm pheromones to communicate with other bees about the danger. In addition, *A. cerana* provides considerable economic benefits to the apicultural industry through its high-quality bi-products, perhaps more than *A. mellifera* (Park et al. 2015). *A. mellifera* has been subdivided into at least 20 recognized subspecies or races (Koetz, 2013). Similar to *A.*

mellifera, there are eight recognized subspecies of *A. cerana*. These subspecies tolerate a good range of temperatures from cold, temperate, to tropical ecosystems.

Even though *A. mellifera* produces a large amount of honey per colony, the indigenous *A. cerana* is profitable over *A. mellifera* because *A. mellifera* requires intensive management, standardized equipment, and larger foraging areas. *A. cerana* exhibits high tolerance to seasonal low temperatures as compared to *A. mellifera* and as a result, it is the first active honeybee on cool mornings in the northern tropics (Corlett, 2010).

MATERIALS AND METHODS

A review of the published literature in national and foreign journals, proceedings, reports, newsletters, and books has been made in an effort to compare the *A. cerana* and *A. mellifera*.

LITERATURE REVIEW

Comparison of morphological characteristics of A. melifera and A. cerana

In general, *A. cerana* is smaller than *A. mellifera*. Apart from a few conspicuous qualitative characteristics which are mainly used to discriminate between the very similar species *A. cerana* and *A. mellifera*, e.g., the radial vein of the hind wing, the tomentum on the sixth tergite or the absence of chitinous plates on the endo phallus, others are found which are also specific for *A. cerana*. *A. cerana* have more prominent and consistent striping on their abdomen with even black bands across the abdomen, whereas *A. mellifera* tend to have uneven black stripes with thinner stripes at the front and thicker black stripes towards the rear which makes it more yellow at the front and darker at the back of the abdomen. The most reliable morphological characteristic of *A. cerana* is the extension of the radial vein on the hind wing, which is absent in *A. mellifera*. The differences between *A. cerana* and *A. melifera* are most striking in the male genitalia, while they are easily overlooked in the female castes (Ruttner, 1988). The abdominal stripes (tomenta) of *A. cerana* are more pronounced than those of *A. mellifera*, and *A. cerana* workers have four abdominal stripes, whereas *A. mellifera* workers have three abdominal stripes.

Ecology and behavior

Foraging behavior

Bees gather nectar and pollen from blossoms and facilitate pollination at the same time. Nectar is later turned into honey by the bees in a nest, to provide energy in the form of carbohydrates for the colony. Foraging is one of the distinctive behaviors of honey bees which is the link between the honey bee colony and the ambient environment.

Table 1. Comparison of several specific characters between *A. cerana* and *A. melifera*.

Characters	*A. cerena*	*A. melifera*
Labrum - pigmentation	All yellow or brown	All dark or dark with yellow mark
Tibia of hind leg - drone	Grove (longitudinal)	Round
Cubital index (mean value)	4.40	2.30
Hooks on hind wing (mean value)	18.28	21.30
Endophallus Chitinous plates Upper cornua Fimbirate lobe	 Absent Three pairs Rosette-like	 Present Rudimentary Feather-like

Source: (Ruttner, 1988)

On a single foraging trip, *A. cerana* foragers tend to collect either pollen or nectar (not both) from a single species of plant, continuing to collect pollen or nectar from that plant throughout the day (Corlett, 2010). Foraging ranges of *A. cerana* vary between different studies, but maximum foraging ranges of 1,500 m to 2,500 m have generally been observed. In comparison, *A. mellifera* tends to forage across much larger distances, with maximum distances of over 10 km (Beekman and Ratnieks, 2000). Honeybees start and finish foraging often depending on ambient temperature, humidity and/or light levels of the day, as well as the availability of floral resources. In general, *A. cerana* tend to start foraging earlier than *A. mellifera*, as it requires slightly lower temperatures, light intensity and solar radiation levels to commence flight activity than *A. mellifera*. However, *A. mellifera* start foraging later than *A. cerana* because of its larger body size that requires a higher thoracic temperature, and *A. cerana* are thus more adaptable to extreme fluctuations in ambient temperature and long periods of rainfall (Tan et al. 2012). *A. cerana* is more industrious in collecting nectar from scattered flowers, while *A. mellifera* worker has a stronger foraging capacity of large flower patches (Feng et al. 2014).

Fanning behavior

Honeybee colonies are able to maintain brood nest temperature within the range of 33–36˚C, even when the ambient temperature ranges from well below freezing to above 45˚C (Fahrenholz et al. 1989). Fanning bees stand on the landing platform at the doorway to their hive and produce a current of air by beating their wings, which serves as air-condition to the hive. Since they remain for up to five minutes in the same spot by gripping the floor with their claws, their regular wing movements present a state of 'flight' suitable for studying without fixing the animal (Junge, 2006).

One of the recognizable differences between *A. cerana* and *A. mellifera* is the fanning position of workers at the hive entrance in which *A. cerana* workers ventilate the hive by fanning away from the entrance with their head, whereas *A. mellifera* fan with their heads turning facing the entrance. The entrances of hived bees are generally at the bottom of the nest/hive. So, *A. cerana* workers face upwards, whereas *A. mellifera* workers face downwards (Ruttner, 1988).

Nest characteristics

Combs

A. cerana build multiple comb nests in dark cavities, although open nests (e.g., built underneath building eaves) have also been observed. Combs are built parallel with a uniform distance between the bee spaces. Honey is stored in the upper and outer combs adjacent to the cavity walls and the remaining comb space is taken up by brood of various ages. The number of combs in *A. cerana* nests varied from three to fourteen combs. *A. cerana* cells are of two sizes: generally smaller worker cells and larger drone cells (Phiancharoen, et al. 2010). In comparison, the A. mellifera worker cell is larger than that of *A. cerana*. *A. cerana* drone cells have a raised cap with a distinctive pore at their apex. The size difference between worker cells and drone cells is less noticeable in *A. cerana* than in *A. mellifera*. Large conical queen cells are built on the lower edge of the combs. However, just like body size, worker cell size also varies geographically and is larger in colder regions.

The wax of *A. cerana* has a melting point of 65°C which is about 2°C higher than that of *A. mellifera* (Ruttner, 1988). The drone cell is capped by the worker bees with a wax cover and the drone larva spins the cocoon. However, 1-3 days after completion of the cover, bees start to remove the wax and then a yellowish, hard, silky plate appears. Wherever the behavior of *A. cerana* has been studied, no use of propolis was found and the cracks in the hive are not sealed. However, a brittle and light greyish mass is present on hive walls and frames, which is not pure wax.

Colony Defense

A. cerana is generally docile, gentle, mild, tolerant and timid in defense behavior. *A. cerana* shows a number of behavioral changes which prove to be very effective against traditional enemies. Finally, *A. cerana* has several unique responses to disturbances including fast and sudden lateral body shaking of workers, the production of a hissing sound, and heat balling.

Hissing sound

When the beehive is disturbed or a certain enemy attacks, it induces a sharp hissing sound that lasts about 0.5 s. The sound is produced by a collective quick closing of the wings over the body and the abdomen jerks upward. The reaction is transmitted to bees, besides immediate contact with the stimulating agent, by body contact; it migrates over the comb or the bee cluster with a velocity of 3 cm per second (Koeniger and Fuchs, 1973).

Group defense

Similarly, if it is attacked by powerful enemies such as hornets, *A. cerana* bees do not counter-attack, as most races of *A. mellifera* do. But, *A. cerana* forms groups of 30 with the tip of the abdomen raised near the entrance. The shy *A. cerana* stops flight activities on a hornet's arrival. The hissing sound is repeatedly emitted in the hive. After this rapid retreat with no solitary counter-attack the hornet usually relinquishes its attempt and leaves. If hornets persist in the attack, they do not dare to capture bees out of the group. But, if the hornet approaches too closely, it is seized simultaneously at the legs and wings by several bees and drowned in the mass of bees and killed. In most of the observations, virtually no bees died during the defense. The hornet attacks are stopped at the very beginning.

Heat balling

Heat balling is a unique defense of *A. cerana* to kill predatory hornets like Vespa simillima xanthoptera. Several hundred bees surround the hornet in a tight ball and vibrate their thoracic muscles to produce heat. The *A. cerana* workers are able to raise the temperature inside the ball to an average of 46°C for approximately 20 minutes. This temperature is high enough to kill the hornet inside, but not high enough to kill the bees, who can tolerate temperatures up to 48 and 50°C. *A. mellifera* workers also will surround a hornet, but they are not able to raise the temperature as high as can *A. cerana*. Instead, *A. mellifera* workers primarily sting the hornet and are less effective at eliminating the hornet. So, the attacks on *A. mellifera* colonies by Vespa develop quite differently as it waits for the attacking bees, seizes and kills them with its strong mandibles and transports the corpses back to the nest. When the number of hunting wasps increases with the decrease in the defense reactions of the bee colony, the wasps kill one bee after the other without carrying the corpses to their nest, until the resistance ceases and they succeed in occupying the beehive and eating or transporting pupae and larvae. At the entrance of the occupied hive, the territorial defense behavior of the wasps is observed (Matsuura and Sakagami, 1973). *A. cerana* is the only potential prey of *V. mandarinia* which has developed an effective defense tactic. Group defense behavior evidently represents a higher level of cooperation than individual counter-attacks.

Stinging behavior

A. cerana is in general less prone to sting than *A. mellifera*. *A. cerana* has a reduced frequency of sting apparatus autotomy. This is due to a change in behavior by revolving movements after stinging instead of straight runs and by strong muscles anchoring the sting apparatus to the spiracle plates. *A. cerana* uses its mandibles instead of the sting when attacking an enemy which resulted in the reduction of the sting-protracting muscles. Of all Apis species, *A. cerana* has the least developed barbs on the lancets of the sting (Koeniger et al. 1979). The venom of *A. cerana* is identical to that of *A. mellifera* in the amino acid sequence of the melittin, its main component. Isopentyl acetate, an alarm substance was found in worker bees in much lower quantities than in mellifera.

Robbing and direct fighting

When species come to overlap geographically and compete for the same limited resources, either a competitive exclusion or niche partitioning will occur. It is possible that the ecological and behavioral differences between A. mellifera and A. cerana will result in sufficient niche partitioning so that both species can co-occur successfully (Sharma, 2000). Both species can also coexist if resources are not limited. Floral resources and nest cavities are the two most important resources for cavity-nesting honeybees. Competition for pollen and nectar may occur on flowers, or they can attempt to rob honey from other nests that can be of the same a different species.

Robbing bees enter another colony's nest, kill bees and take their honey store. The smaller the colony the more susceptible it is to robbing (Partap, 2011). Robbing occurs when floral resources are low, nectar flow is interrupted, or a colony is weak or diseased. Interestingly, *A. mellifera* showed a much stronger defense response than any of the Asian honeybees (Breed et al. 2007). Studies on robbing behavior between managed hives of two species kept at the same apiary showed that *A. mellifera* usually won by killing *A. cerana* colony and taking over the foraging area although *A. cerana* initiated robbing during lean times. No effective defense reactions are developed in *A. cerana* to robbing attempts by *A. mellifera*. There are no guard bees at the entrance so, intruders can pass easily without being inspected and also sometimes robbed *A. cerana* bees were observed to feed the robber bees (Ruttner, 1988). During the hot season *A. cerana* colony attacked by *A. mellifera* bees usually loses all its stores and then absconds or dies. Overall, evidence suggests that *A. cerana* is a weak nest defender and competitor as compared to *A. mellifera*. Compared with *A. cerana*, *A. mellifera* has a larger body size, longer flight range and stronger defensiveness. *A. mellifera* thus shows advantages in nectar robbing, nuptial flights and mating and disease-transmitting (Tan et al. 2012).

Brood development

The development of *A. cerana* is similar to that of Apis species in general, and that of *A. mellifera* in particular. *A. cerana* brood development is slightly faster than that of *A. mellifera*, except for *A. cerana* queens (Table 2) (Koeniger et al. 2010). However, it seems doubtful that this slight difference will affect competition or invasiveness. Like in other cavity-nesting species, the larva's brood cell is capped by the worker bees just before the last of the five larval instars.

Table 2. Duration of the life cycle (days) of different castes of *A. cerana* and *A. mellifera*

Stage	Worker		Drone		Queen	
	A. cerana	*A. mellifera*	*A. cerana*	*A. mellifera*	*A. cerana*	*A. mellifera*
Egg to larva	3	3	3	3	3	3
Larva to pupa	5	6	6	7	4-5.5	5
Pupa to adult	11	12	14	14	6-7.5	5
Total	19	21	23	24	13-16	13

Source: Koeniger et al. 2010

Swarming and absconding

Reproductive swarming and absconding are the two types of swarming in honeybees. Reproductive swarming involves the splitting of a colony and movement of the old queen with more than 70 % of the colony to a new nest site, while the new queen stays with the remaining colony and all its resources in the old nest site. It generally occurs when conditions are favorable and floral resources are abundant (Chinh et al. 2005). There are two types of absconding

i. Seasonal absconding/migration: movement of the whole colony due to resource depletion, declining nest site quality

ii. Disturbance-absconding: acute disturbance through natural causes like fire, flooding, or anthropogenic like intervention by beekeepers.

Migration is a resource-related and is a seasonal movement of tropical honeybee colonies without any reproduction. It maximizes the colonization of new areas and provides a spatial refueling cycle clearly driven by reselection. To migrate/abscond, bees must have sufficient flight fuel and energy reserves so that, they can construct new combs at a new site. Absconding colonies typically expand honey, accelerate wax production, reduce oviposition and consume eggs and young larvae so conserving protein. Absconding/migration may be beneficial to the survival, dispersal and propagation of honeybees, but imposes serious difficulties for beekeeping in the tropics (Hepburn and Radloff, 2011) Honeybees prepare for the move (lasting days to weeks) prior to moving, when foraging, reduce honey and brood levels during seasonal absconding but no such preparation occurs before disturbance absconding. In general, tropical honeybees including African strains of *A. mellifera*, are more prone to absconding than temperate species due to the change in temperature, humidity, and resource levels. This means tropical honeybees are able to move throughout the year in response to change or disturbance, and to follow the honey flow, both of which increase fitness and survival (Ruttner, 1988).

Seasonal absconding

Seasonal absconding is directly related to resource depletion and adverse environmental conditions of the current location. *A. cerana* don't store large amounts of honey so they have no sufficient stores to last for long. So, they move continuously to find better conditions elsewhere during periods of high temperatures and dry seasons, after the abatement of prolonged heavy rains (Hepburn and Radloff, 2011). Absconding has also been found highest in areas with high environmental uncertainty like drought, and when nest cavities are too small for the growing colony. However, studies on *A. cerana* have also observed absconding regardless of colony size, congestion, or food supply (Hepburn, 2011) or without an apparent external cause.

A. cerana prepare for migration by decreasing the numbers of pollen-carrying workers, reducing brood feeding and rearing, and reduced predator and parasite defense, decreasing honey and pollen stores, eggs which leads to large changes in colony demography (Pokhrel et al. 2006). *A. cerana* abscond less often than open-nesting Asian honeybee species but more often than temperate *A. mellifera*. Temperate *A. mellifera*, especially wild colonies, may abscond for to the same reasons as tropical honeybees due to depleting resources and starvation, predation, disturbance, adverse environmental conditions, and disease/parasitism (Ruttner, 1988).

Predation (Disturbance absconding)

Tropical honeybee species are under more severe predation pressure than temperate honeybees. Predation is an important and powerful force in the evolution of Asian honeybees, shaping choice of nest site, nest architecture, population size, worker morphology, and behavior. Natural predators of A. cerana include wasps, ants, vertebrates (tiger, human, birds etc.), and hornets, which tend to prey on foragers but also at times attack colonies. In cavity-nesting Apis species, the main defense against predators is living in a protected cavity with a small entrance that can be easily guarded. Colony defense behaviors include abdomen shaking, hissing (through wing vibrations), group defense (including grasping, pulling, and biting, killing by overheating and/or asphyxiation), and stinging (Ruttner, 1988).

Reproductive swarming

Reproductive swarming in *A. mellifera* occurs when floral resources are abundant and a colony is performing well (Chinh et al. 2005). Soon after a swarm has left the old nest, *A. mellifera* settles tens of meters away and scouts will start searching for suitable nest sites. Similarly, *A. cerana* also settles 20 ± 30 m away from the old nest for several days and then moves to the new nest site. *A. mellifera* colonies are prevented from swarming by good colony management, removing new queen cells, re-queening and using queen excluders. Wild, temperate *A. mellifera*, however, swarm nearly every year and sometimes up to three times per seasonal cycle when resources are highest. Swarming of *A. cerana* is highly variable and depends on the geographic location and climate. *A. cerana* can swarm several times a year (Ruttner, 1988). According to Koeniger et al. (2010), swarming will start when a colony reaches 20,000 bees, with an average of eight swarms per colony. The timing of swarming has been found to vary from no seasonal rhythm, biphasic, to distinct times of the year (Hepburn, 2011).

When foraging conditions are good over a long time, swarming will occur more frequently resulting in the asynchronous production of queens and drones (Chinh et al. 2005). When foraging conditions are good only at certain times of the year (e.g., spring and summer in temperate zones), swarming will occur during those specific times, and swarming and the production of queens and drones will be synchronous as seen in temperate *A. mellifera* (Hepburn, 2011).

Diseases and Hygiene

Where honeybee species coexist, they are bound to interact in some way like robbing due to which parasites and pathogens can be transmitted between species. Diseases and parasites have been introduced from *A. mellifera* to *A. cerana* like the tracheal mites as well as Israeli acute paralysis virus and Varroa destructor from *A. cerana* to *A. mellifera*. *A. cerana* diseases include bacterial infections such as American and European foulbrood, protozoan and fungal infections like *Nosema ceranae* and *N. apis* and chalkbrood, and virus infections like Apis Iridescent virus, Deformed wing virus, Thai sacbrood virus, black queen cell virus etc. *A. cerana* parasites include Varroa (*V. destructor*, *V. jacobsoni*, and *V. underwoodi*) and tracheal mites (*Acarapis woodi*), as well as non-parasitic mites (Kojima et al. 2011). *Varroa jacobsoni* Oudemans is widespread throughout the cerana area. However, no severe damage is caused to *A. mellifera* due to absence of a particular host-parasite relation (Ruttner, 1988). *A. cerana* workers were found to clean themselves more thoroughly than *A. mellifera*. In addition, infected brood is either removed before capping (e.g., larvae infected with American foulbrood or worker brood with Varroa), or is entombed (e.g., drone larvae infected with Varroa) (Rath, 1999). Experiments showed that immediate cleaning behavior in *A. cerana* is due to the presence of Varroa semiochemical compounds. *A. cerana* are regarded as hardy and disease-resistant than *A. mellifera*, making it a better species in many poorer areas of Asia as *A. cerana* requires less management and treatment for diseases (Russo et al. 2020).

CONCLUSION

Hence, *Apis cerana*, an Asian honeybee and *Apis mellifera*, European honeybee are the two most important bee hives found in the wide range of the world. Both the species are cavity-nesting bee hives and are popular for their high-quality honey production and a good pollinator. *A. cerana* can tolerate a wide range of temperatures and are of shy nature, hardy and disease resistant as compared to *A. mellifera*. *A. cerana* is smaller than *A. mellifera* in average and have a similar life cycle. *A. cerana* are capable of defending themselves against enemies or disturbance and are conscious about their hygiene in comparison to *A. mellifera*.

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