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Role of Pheromones in Honeybee Behaviour and Its Practical Utility

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In Honeybees, pheromones play an important role in communication behaviour. Pheromones like queen bee mandibular pheromone and retinue pheromones are mainly involved in the coherence of unity of the colony. Synthetic queen pheromone helps to avoid the time and labour invested for queen rearing and swarming. Introduction of worker brood with their inhibitory pheromone would prevent production of laying workers. Foraging may be increased by brood pheromone by providing the larval extracts. Synthetic mating pheromones could be used to survey the flight distribution pattern of drones and artificial mating station can be established in order to prevent inbreeding. Application of synthetic alarm pheromone a few minutes ahead of insecticide application in the field might help to reduce any bee losses to acceptable levels and it also repel the robbers when applied at hive entrance.

Introduction

Communication in any organism will play a trivial role in their successful growth and development. Insects utilize different kinds of signals for their communication. Particularly in Honeybees, pheromones play an important role in specific behaviour. This helps them to render their successful life in the ecosystem and also to sustain their communal life.

Pheromones

Pheromones are substances secreted by an organism to the outside environment trigger a specific response in the behaviour of the receiving individual of same species. Honey bee pheromones have both releaser effect through sex attraction, alarm and aggregation, trail production, clustering and mutual recognition and primer effect through inhibition of mandibular glands, Nasanov glands, Koschevnicov's gland, sting glands, Dufour's gland wax glands and Arnhart gland (tarsal gland) are the important sites of pheromone production.

Mode of Transmission

Highly volatile components of low molecular weight notable among which are the alarm pheromones and attractant pheromones are transmitted in the air. Other pheromones functioning within the host are relatively nonvolatile and perceived by contact chemoreception. Long chain paraffins in the cuticular wax of honey bees tend to act as fixatives. They are responsible for brood recognition, caste regulation and colony odour. They are passed through the inmates either by direct body contact or in the food supply. They may also deposit and perceived on the surface of the comb. Three modes of transmission is proposed such as, transmission by food exchange

between workers, volatile transmission and transmission between body surfaces of workers, particularly during antennal contacts. Pheromones are distributed over queen's body by her grooming, picked up by direct contacts between workers and the queen, and then transported throughout the colony by these messenger bees. Queen substances act on the worker's hormonal system and inhibit the ovary development when the pheromones are transmitted internally from the worker's body surface. They also used to mark the enemies and some are used to mark the floral sources.

Types of Honeybee Pheromones

1. Queen honey bee pheromones

a. Queen mandibular pheromone (QMP)

QMP affects social behaviour, maintenance of the hive, swarming, mating behaviour, and inhibition of ovary development in worker bees. Some of the chemicals found in QMP are carboxylic acids and aromatic compounds. 9- keto (E) 2 decenoic acid (9-ODA) inhibits queen rearing and ovarian development in worker bees and strong sexual attractant for drones during nuptial flight. (S) 9-hydroxy-(E) 2-enoic acid (9-HDA) promotes stability of a swarm, or a calming influence. Homovanillyl alcohol in QMP plays a key role to behavioural modifications. Other compounds include methyl-p-hydroxy benzoate, 4-hydroxy-3-methoxy phenyl ethanol (HVA). Synthetic queen mandibular pheromone (QMP) is a mixture of five components 9-ODA, (-) isomer (9-HDA), (+) isomer of (9-HDA), HOB and HVA in a ratio of 118:50:22:10:1

b. Queen retinue pheromone (QRP)

QRP comprises of methyl (Z)-octadec-9-enoate (methyl oleate), (E)-3-(4-hydroxy-3-methoxyphenyl)-prop-2-en-1-ol (coniferyl alcohol), hexadecan-1-ol, (Z9,Z12,Z15)-octadeca-9,12,15-trienoic acid (linolenic acid) are important for the retinue attraction of worker bees around their queen.

Table 1. Functions of queen producing pheromones

Functions	Chemical responsible
Inhibition of queen rearing and swarming, queen attractiveness and recognition, stimulation of Nasanov pheromone release and worker foraging	9 ODA and 9 HDA
Prevention of worker ovary development	9 ODA
Attraction to swarms	9 ODA
Swarm cluster stabilization	9 HAD

2. Alarm pheromone

When danger is imminent, alarm pheromones serve the dual roles of being used to muster the help and to direct the attack. The alarm pheromone is released by sting glands and the pheromone dispersal is aided by fanning of wings. Two main alarm pheromones have been identified in honeybee workers. One is from the Koschevnicov's gland, near the sting shaft, and consists of isopentyl acetate and butyl acetate, 1-hexanol, *n*-butanol, 1-octanol, hexyl acetate, octyl acetate, n-pentyl acetate and 2-nonanol. These chemical compounds have low molecular weights, are highly volatile, and appear to be the least specific of all pheromones. The other is from Mandibular glands produce 2 – heptanone acts as an alerting pheromone which is mainly used to repel the robber bees. Smoke can mask the bees' alarm pheromone by blocking the antennal receptors. The amount of 2-heptanone increase with the age of bees

and becomes higher in foragers and it is used to scent-mark recently visited flowers to signal other foragers (Palaniswamy *et al.* 2004)

3. **Brood recognition pheromone**
   It is responsible for preventing worker bees from bearing offspring in a colony that still has developing young. Both larvae and pupae emit brood recognition pheromone. This inhibits ovarian development in worker bees and helps nurse bees to distinguish worker larvae from drone larvae and pupae and also the sex and caste. This pheromone also modulates adult caste ratios and foraging ontogeny dependent on its concentration. The amount of pollen a colony collects increases with the amount of worker brood is rearing. The components of brood pheromone have been shown to vary with the age of the developing bee.

4. **Navigation pheromone**
   Honey bees use the odours emanating from their colony to locate the entrance to their nest on return from the field and use the odours emanating from individual bees to help them distinguish friend from foe. Foraging honey bees that have found the entrance to their hive after being temporarily disoriented release Nasanov pheromone at the hive entrance.

5. **Comb pheromone**
   Some pheromones are known to incorporate into comb as it is built subsequently added to the cells may stimulate or regulate various activities of the colony. Comb and pheromones have stimulatory effects other than hoarding and foraging. Colony defense is also encouraged by the presence of empty comb.

6. **Trail or foot print pheromone**
   Honey bee workers involuntarily deposit pheromones that attract others both when foraging and when entering their nest. Workers entering their hives deposit a persistent attractive material. The trail pheromone is secreted either by tarsal gland or from all over the body. Honey bees mark the rewarding flowers with stable trail pheromone with an attractive odour while unproductive food source with a deterrent pheromone. This pheromone is left by bees when they walk and is useful in enhancing Nasonov pheromones in searching for nectar (Palaniswamy *et al.* 2004).

7. **Drone pheromone**
   Drones produce a pheromone that attracts other flying drones to promote drone aggregations at sites suitable for mating with virgin queens.

8. **Dufour's gland pheromone**
   The Dufour's gland secretes some alkaline products in to the vaginal cavity, and it is assumed to be deposited on the eggs as they are laid. Dufour's secretions allow worker bees to distinguish between eggs laid by the queen, which are attractive, and those lay by workers. This also helps to locate queen right colonies by workers.

9. **Egg marking pheromone**
   This, helps nurse bees distinguish between eggs laid by the queen bee and eggs laid by a laying worker.

10. **Nasonov pheromone or scent gland pheromone**
    The Nasanov gland is present only in workers (on 7^{th} abdominal tergite). Important chemicals identified in the glands are geraniol, nerol, farnesol, citral, geranic acid and neronic acid. Synthetic scent lures can be prepared with (E) and (Z) citral, geraniol and

nerolic and geranic acid at 1:1:1 ratio and used for orientation for food, water and to mark the temporary swarm clustering site.

11. Primer/ forager pheromones

Primer pheromones play an important role in distributing the labour in honey bees. The forager bees feed this primer pheromone to the worker bees, and the chemical keeps them in a nurse bee state. The pheromone prevents the nurse bees from maturing too early to become forager bees. As forager bees die off, less of the ethyl oleate is available and nurse bees more quickly mature to become foragers (Haung *et al.,* 2004).

12. Mating pheromone

9-ODA was found to be the mating pheromone for honey bees and its is responsible for the sexual attractant and congregation stimulant for the drones (Gary, 1974). Synthetic mating pheromone could be useful for the enhancement of mating in honeybee species.

12. Other pheromones

Apart from these, other pheromones produced by most honeybees include rectal gland pheromone, wax gland and tergite gland pheromone used in colony stabilization.

Applications of pheromones in bee keeping (Sharma, 1996 and Palaniswamy *et al.* 2004)

- Synthetic queen pheromone can be of great value for avoiding the time and labour invested for queen rearing and swarming
- Introduction of worker brood with their inhibitory pheromone would prevent production of laying workers and their brood in queen less colonies and associated difficulties in introducing new queens
- Foraging may be increased by brood pheromone possibly by providing the larval extracts or using a simple device to channel foragers from the entrance to the brood combs. This will also help in collecting good quantity of pollen
- The mite *Varroa jacobsoni* is a parasite of honey bees will lay more eggs on drones. So, development of synthetic drone pheromone lure could help to manage this mite
- Synthetic mating pheromones could be used to survey the flight distribution pattern of drones in sweep nets. Artificial mating station can be established by creating artificial drone congregating zone to prevent inbreeding
- Simple and inexpensive traps contain the Nasanov lure have proved to be effective and competitive means of capturing honey bee swarms and moving to a particular site and attracting the scout bees to potential nest sites
- Application of synthetic alarm pheromone a few minutes before an insecticide application in the field might help to reduce any bee losses to acceptable levels. It would only be necessary to apply the alarm pheromone to the borders of the field as foragers leaving or returning to the field would then become aware of it.
- Application of synthetic alarm pheromones at the hive entrance could repel robbers and ensure the defenders are alert.

Conclusion

Among different methods of communication, pheromone mediated signal transmission is highly safe for the communicating species in order to prevent the cross talk with its natural enemies and aids better evolution for them and these lead to development of better communication behavior in the species. In that context, honey bee occupied the superior hierarchy in the evolution of communication behavior. Among different pheromones detailed above, the successful role of

alarm pheromone and queen bee pheromones were already proved under field conditions. Hence, there are vast scope for the development and application of various synthetic honey bee pheromones with more viability and shelf life. This would help in the maintenance of bee colonies with sufficient population, good hygiene, ideal foraging ability and maximum commercial utility.

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