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How do workers of the primitively eusocial wasp *Ropalidia marginata* detect the presence of their queens?

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Abstract

Queens in primitively eusocial insect societies are morphologically indistinguishable from their workers, and occupy the highest position in the dominance hierarchy. Such queens are believed to use aggression to maintain worker activity and reproductive monopoly in the colony. However, in the primitively eusocial wasp *Ropalidia marginata*, the queen is a strikingly docile individual, who interacts rarely with her workers. If the queen is experimentally removed, one of the workers becomes extremely aggressive within minutes, and eventually becomes the new queen of the colony. We designate her as the potential queen. Experimental evidence suggests that the queen probably uses a non-volatile pheromone to signal her presence to her workers. Here we attempt to identify the mechanism by which the queen transmits information about her presence to the workers. We designate the time taken for the potential queen to realize the absence of the queen as the realization time and model the realization time as a function of the decay time of the queen's signal and the average signal age. We find that the realization time obtained from the model, considering only direct interactions (193.5 min) is too large compared to the experimentally observed value of 30 min. Hence we consider the possibility of signal transfer through relay. Using the Dijkstra's algorithm, we first establish the effectiveness of relay in such a system and then use experimental data to fit the model. We find that the realization time obtained from the model, considering relay (237.1 min) is also too large compared to the experimentally observed value of 30 min. We thus conclude that physical interactions, both direct and indirect (relay), are not sufficient to transfer the queen's signal in *R. marginata*. Finally, we discuss the possibility that the queen applies her pheromone on the nest material from where the workers can perceive it without having to physically interact with the queen.

Keywords: Queen pheromone; Relay interactions; Dijkstra's algorithm; Potential queen; Rub abdomen behaviour

1. Introduction

In a typical primitively eusocial wasp, where there is no queen-worker dimorphism, the queen is the most behaviourally dominant member of her colony. In such species, the queen maintains her reproductive monopoly by means of physical aggression toward her workers, and especially toward the beta individual, who succeeds her if she dies (Fletcher and Ross, 1985; Gadagkar, 1991; Reeve, 1991; West-Eberhard, 1969, 1977).

Ropalidia marginata (Lep.) (Hymenoptera: Vespidae), is classified as a primitively eusocial species due to the absence of queen-worker dimorphism (Gadagkar, 2001). However, *R. marginata* queens are strikingly docile and behaviourally non-dominant individuals. Nevertheless they are entirely successful in maintaining reproductive monopoly in their colonies. Upon the death or removal of the queen, one individual becomes extremely aggressive and goes on to become the next queen if the original queen is not returned. We refer to this individual as the potential queen (PQ). Invariably, the PQ significantly alters her behaviour within minutes of queen removal (Gadagkar,

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