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RESEARCH ARTICLE

Path minimization in a tandem running Indian ant in the context of colony relocation

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ABSTRACT

The phenomenon of minimizing the path length to a target site in order to increase transport efficiency is described as path optimization, and it has been observed in many mammals, birds and some invertebrates such as honeybees and ants. It has been demonstrated that ants can optimize their foraging path through an emergent process, involving the trail pheromone concentration, without individual ants having to measure and compare distances. In the current study, we investigated whether ants that use only tandem running to recruit their nestmates can minimize their path while relocating their entire colony into a new nest. As colony relocation directly impacts the survival of the whole colony, it would be particularly important to optimize their path to the new nest. Using the ponerine ant *Diacamma indicum*, we conducted relocation experiments, in which ants had to choose between different defined paths, and contrasted our findings with open arena experiments, as they navigated to their new nest. After following 4100 unique transports by 450 different transporters, we found that these ants do minimize their path. Individual leaders, as well as colonies, chose the shorter path significantly more than the longer path, and they showed a significant preference for the shorter arm at multiple decision points on encountering a combination of paths. Thus, we concluded that tandem leaders are capable of path minimization based on the information they themselves collect. Further investigation into the proximate mechanisms by which they achieve this is required.

KEY WORDS: Insect navigation, Ant colony optimization, Non-trail laying ants, *Diacamma indicum*

INTRODUCTION

Animals would be expected to optimize their path when they visit a location multiple times. The phenomenon of path optimization has been documented in the context of foraging in a wide range of animals. Many vertebrates like bats (Lemke, 1984; Racey and Swift, 1985), birds (Davies and Houston, 1981; Gill, 1988), rodents (Reid and Reid, 2005) and primates (Janson, 1998; Watts, 1998; Noser and Byrne, 2010) are known to minimize their path length. Social insects like bumblebees (Heinrich, 1976; Gilbert and Raven, 1980; Ohashi and Thomson, 2009), honeybees and ants are also capable of path optimization in the context of foraging. Ants that use chemical trails to recruit their nestmates, like *Linepithema humile* (previously known as *Iridomyrmex humilis*) are known to use simple means to minimize their path. Elegant experiments have demonstrated that a combination of being able to differentiate concentration gradients and the longer time required for pheromone concentration to build upon the longer trail was sufficient for the shortest path to emerge as the path of choice, without individual ants themselves having to measure the different distances (Goss et al., 1989). This finding allowed us to appreciate how ants can choose the best solution in a collective manner by following a simple set of rules. It also allows us to wonder if individual ants are capable of deciphering the shortest route with the information that they themselves collect. Furthermore, it would be equally important for non-trail-laying ants to minimize their path. Thus, it is essential to explore if individual ants and colonies of non-trail laying ants can optimize their path.

While pheromone trails are widely used in ants, various species with small colony sizes, rely on other mechanisms such as carrying, tandem running, and in some cases, both (Pratt et al., 2002; Pratt, 2008; Franklin, 2014). Some researchers hypothesize that pheromone trails are easier to maintain for large colonies compared with smaller colonies, as pheromone trails require constant reinforcement. Even though many small-sized colonies do use pheromone trails, they are likely to pay a higher price for maintaining them and alternative mechanisms may have evolved (Beckers et al., 1989; Hölldobler and Wilson, 1990; Beekman et al., 2001; Detrain and Deneubourg, 2008; Planqué et al., 2010; Lanan, 2014; Czaczkes et al., 2015). Carrying is the transport of an individual ant in the mandibles of another ant. Tandem running is the movement of a pair of ants that are in physical contact from one location to another. Typically, the ant that initiates the tandem run and takes the lead is termed a 'tandem leader'. This individual is familiar with the destination and takes the follower to it (Möglich et al., 1974; Hölldobler and Wilson, 1990). Tandem running is used to recruit for various purposes like foraging, slave raids and colony relocation in different species of ants (Franklin, 2014). In a few species – *Leptothorax acervorum*, *Temnothorax albipennis* and *Diacamma rugosum* – tandem leaders are known to lay individual-specific markings along the path they travel or inside potential new nests (Möglich, 1979; Mallon and Franks, 2000; Maschwitz et al., 2010; Basari et al., 2014).

In the current study, we examined the ability of *Diacamma indicum*, a ponerine ant with small colony size that recruits their nestmates only through tandem running (Kolay and Sumana, 2015), to minimize their path in the context of colony relocation. Choosing a particular path for foraging or relocation will be dependent on the length of different available paths and other factors such as the presence of predators, obstacles and hostile neighbors. Colonies would not only have to minimize their path length but have to decide on the most optimum path considering all other factors. In the current study, we only examined path minimization in terms of length, as all other factors were kept constant. *D. indicum* is found in India, Sri Lanka and possibly in Japan. Their colony size ranges

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