Ophiocordyceps and Ants: The Fungus That Controls Behaviour

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ABSTRACT

Ants, known for their complex social organization and ecological dominance, interact with a wide range of organisms, including parasitic fungi such as *Ophiocordyceps unilateralis*. This paper explores how this fungus infects and manipulates its ant hosts. After infection, the fungus invades the ant's body and nervous system, compelling it to exhibit abnormal behaviour, leaving the colony, climbing vegetation, and performing the fatal 'death grip'. This behaviour benefits the fungus by providing an ideal environment for spore dispersal. The discussion highlights the role of host specificity, genetic interactions, and the broader ecological impact of such parasitic relationships in regulating ant populations and maintaining ecosystem equilibrium.

INTRODUCTION

Ants are among the most widespread insects on Earth, living in organized colonies that function as a single unit (Beshers and Fewell, 2000; Barbero *et al*., 2023). With over 17,000 known species, they dominate terrestrial ecosystems through their abundance and biomass (Parr and Bishop, 2022; Schultheiss *et al*., 2022). Their colonies provide a rich source of resources and protection, which are exploited by a remarkable diversity of other organisms, including viruses, bacteria and fungi. These associations can be obligatory or facultative, permanent or temporary and may have either

beneficial or harmful effects on ants (Lachaud *et al*., 2012). Among these interactions, the relationship between ants and the parasitic fungus *Ophiocordyceps* is particularly intriguing. This article explores the unique interaction between ants and *Ophiocordyceps*, focusing on how the fungus infects, controls, and ultimately transforms its host.

1. Ant colonies and their success

1.1 Diversity and Ecological Importance: All ants belong to the family Formicidae within the order Hymenoptera. To date, approximately 12,500 living ant species have been described, classified into 307 genera and 21 subfamilies. Four major subfamilies *viz*., Myrmicinae, Formicinae, Ponerinae and Dolichoderinae, dominate, accounting for over 87% of all known species, and encompass the majority of ants commonly found in diverse terrestrial ecosystems. (Guenard, 2013).

Ants play important roles in ecosystems as scavengers, predators, and pollinators. They continuously forage on dead and organic matter, helping recycle nutrients. As natural predators, ants control pest populations by killing harmful insects, reducing crop damage, and improving yields. Their efficiency increases with colony size, and even small numbers can disrupt pests' feeding and egg-laying activities. Additionally, ants act as pollinators for many crops, transferring nectar and increasing the number of flowers and seeds (Sherpa and Devi, 2023).

1.2 Organization and Communication in colonies: Ant colonies are complex, self-organizing systems without central leadership. Workers perform specialized tasks such as foraging, brood care, and nest maintenance. This division of labor is flexible and adapts to the colony's needs, allowing ants to respond efficiently to environmental changes. The organization relies on individual ants' behaviours and interactions, leading to coordinated group actions without hierarchical control. This decentralized structure enables ants to build and maintain complex societies with remarkable efficiency (Moffett *et al*., 2021).

Ants communicate primarily through chemical signals known as pheromones. These substances convey information about food sources, danger, or reproductive status. Foraging ants leave pheromone trails that others follow, facilitating efficient resource collection. Additionally, ants use tactile and vibrational signals to coordinate activities within the nest. This multimodal communication system allows ants to share information and synchronize behaviours, ensuring the colony functions cohesively and adapts to dynamic environments (Moffett *et al*., 2021).

2. Fungal parasites of ants

2.1 The genus *Ophiocordyceps*: Ants are threatened by a fascinating natural enemy: fungi belonging to the genus *Ophiocordyceps* (Araujo *et al*., 2015). The genus *Cordyceps* was originally created to include ascomycete fungi that infect arthropods and produce sexual spores (ascospores). These spores are formed in specialized fruiting structures called ascomata, which develop on conspicuous stalks, known as stromata, that emerge from the body of the dead host (Evans *et al*., 2011).

2.2 The Zombie-Ant fungus: *Ophiocordyceps unilateralis* is a widespread ant pathogen found across tropical regions and is better known by its former name, *Cordyceps unilateralis*. It was later placed in the genus *Ophiocordyceps*, which was created to include species with non-fragmenting

ascospores. This genus became the type genus of the family Ophiocordycipitaceae and currently includes around 140 recognized species (Evans *et al*., 2011).

3. **Host specificity in parasite-host interactions:** The ability of a parasite to infect a host depends on many factors, both living and non-living. Biotic factors include how often the parasite encounters the host and how well it can survive on it. Host specificity is a key trait, determining whether a parasite can grow and reproduce. Over time, natural selection may lead parasites to specialize on a single host or infect multiple hosts. Differences in host and parasite genetics also influence which interactions are successful (Lin *et al*., 2020).

4. **The case of *Ophiocordyceps unilateralis***

4.1 How the fungus infects ants:

The fungus *Ophiocordyceps unilateralis* begins its life cycle by releasing infective spores from fruiting bodies that grow on dead ants, which come into contact with foraging ants leaving the nest. Once a spore lands on an ant, it germinates and grows silently inside the body, often allowing the infected ant to return to the colony undetected. As the fungus spreads, it takes over the ant's nervous system, altering its behaviour and compelling it to leave the nest and climb vegetation. There, the ant grips the plant tightly in a "death grip," enabling the fungus to consume its body and produce fruiting bodies to release new spores for the next infection cycle (Bekker, 2019).

Fig 1. *Ophiocordyceps* infection stages in ants

4.2 Manipulating ant behaviour: The parasitic fungus *Ophiocordyceps unilateralis* manipulates the ants by secreting specific compounds that alter their behaviour. These compounds majorly affect the ant's central nervous system, leading to symptoms such as full-body convulsions and a loss of fear of heights. Infected ants are compelled to leave their colonies, climb vegetation and bite down on leaves or twigs, anchoring themselves in place. This behaviour is known as 'death grip' which facilitates the optimal growth and spore release of the fungus, ensuring its propagation and survival (Roosmalen and Bekker, 2024).

CONCLUSION

The relationship between ants and *Ophiocordyceps unilateralis* showcases the remarkable complexity of nature. This article provides a comprehensive overview of the fascinating interaction between ants and the fungus, highlighting how it infects, manipulates, and ultimately kills its hosts. These interactions demonstrate the influence of host specificity and genetics on parasite-host dynamics. Beyond affecting individual ants, the fungus helps regulate populations and maintain ecosystem balance. Further research will enhance our understanding of these ecological processes.

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