Mini Review

The relationship between ants and fungal agriculture

Abstract

Mutualism describes positive ecological interactions among species that benefit each other. There can be symbiosis when two different biological organisms interact closely for a long period of time. This symbiotic relationship can be mutualistic, communalistic, or parasitic. One such mutualistic relationship is shared between the Ants and Funguses. This relationship can be tri-way symbiosis also. In that case, ecosystems rely on interactions between fungi and plants, plants and ants and ants and fungi. But it is rare to find symbioses that involve all three partners. The cultivation of fungi thought various types of agricultural systems is considered as one of the prominent breakthroughs in ant evolution. The fungus-growing ants are commonly called as attines. Thenests of these attines are made up of leaves and grasses, which they cut priory and then carryto their nests to grow fungus on which they feed on. An ant has been found to contain a bacterial symbiont that produces certain compounds that fight against infections caused by other group of fungi. These bacterial symbionts are from the genus *Pseudonocardia.*

Keywords: mutualism, fungal agricultural systems, symbiosis, ants and funguses, attines, ant evolution, ecological interaction

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Introduction

Ant and fungus mutualism occurs when ants actively cultivate fungi as food sources like how humans cultivate crops. Several species of *Megalo myrmex* ants and attine ants are involved in this interaction. The survival of some fungi and ants is dependent on one another. Generally, herbivores that feed on plant matter exhibit this type of co-dependency. Microbes (Fungi in this case) are the ideal partner because they are able to turn plant material into a food source that is readily accessible to their host (ants). The leaf cutter ant is the major example for this type of symbiosis. This leafcutter ant belongs to the species of leaf-chewing ants from the genera Acromyrmex.[1] These species are widely seen in South America. But in addition to ants, there are several other species of small arthropods that live in symbiosis with fungi. Many types of fungi (mostly *basidiomycetes*) are actively propagated, nurtured, and defended by fungus growing ants. In exchange, the ants are provided with nutrients that are seen in hyphal tips or gongylidia (hyphal swellings). This hyphal growth is rich in carbohydrates.

Additionally, this symbiotic relationship is supported by a bacterium that resides on the ant's body (cuticle), which secretes antimicrobial agents that are used by the ants to guard their fungi from diseases. Recent study shows that the Actino bacteria responsible for such fungal protection belong to the genus *Pseudonocardia*. In addition to serving as beneficial representations for exploring secondary metabolites, *Pseudonocardia* symbionts are a remarkable source of novel antifungal agents and antibiotics. Surprisingly, the leaf-cutting ants not alone enhance the growth of fungus by their strategical behavior but also protect them from antagonistic pathogens and microbes that are threatening the fungal garden. Along with this mutualistic relationship, there are several more symbiotic relationships that affect the growth of fungal culture. One such diversified group of fungi is *Escovopsis* (Table 1).

Table 1 Types of agricultural systems

Types	Species involved	Characteristics	Examples
1. Lower agricultural system	80 species in 10 genera are practicing.	Smaller nests are constructed and other means are employed besides cutting leaves.	Cultivates Leucocoprineae tribe fungus. Ex: *Leucocoprinus gongylophorus*
2. Higher agricultural system	Practiced by 63 species in 2 genera.	Fungi won't survive without its agriculturalists. Phenotypically changes for easy harvesting.	Clade of *leucocoprineaceous* fungi.
3. Coral fungi agricultural system	Practiced by 34 species (pilosum group) within the genus *Apterostigma*.	Desired fungal tissue culture (non- leucocoprineaceous fungus) was cultivated unlike other attines.	Pterulaceae of order Agaricales are cultivated. Ex: *Pterula verticillata*
4.Yeast Agricultural system	Practiced by 18 species in the (rimosus group) of ant genus *Cyphomyrmex*.	The *Cyphomyrmex rimosus* group evolved growing fungi in yeast form 25 million years ago.	Dimorphic *leucocoprineaceous* fungi are cultivated.
5. Leafcutter agricultural system	Practiced by 40 species in 2 genera (*Atta* and *Acromyrmex*)	As a matter of fact, all types of agriculture use dead biomass to feed fungi, except leaf cutters, which use living biomass.	Highly derived species of fungus. Ex: *Leucoagaricus barsii.*

Symbiotic relationships and partner fidelity

The symbiotic relationship between *Leucoagaricus* fungi and attine ants are not just beneficial relationship but an obligatory one. As the fungus cultivar supplies food for the ants, it restricts their diet to monocultures of gongylidia.[2] The monoculture of *Leucoagaricus gongylophorus* cultivar would be highly prone to infections without the ants. The fungi develop adaptations to perceived threats through modifications of the gongylidia. The presence of gongylidia allows the cultivar to limit the spread of foreign micro flora such as the fungus parasite *Escovopsis* to a certain extent by providing the ants with highly nutritious food, thus producing antifungal feces and few drops of liquid obtained from anus of the ants which are likely to kill alien microorganisms. The saliva of the ants has antibiotics naturally which also helps them in sterilizing the surrounding area.[3] The mycelium (the vegetative part of the fungus) is taken with the queen as she leaves the colony, and is used for creating new fungi gardens at her resting place. It grows into a new fungal farm, where the genes of the original cultivar are shared with a new generation of ants.[4] In many cases, the *Lepiotaceae* is not found outside ant colonies because of the specialized relationship between attine ants and the fungus. A system of feeding the fungus and perpetuating its replication has evolved within these ants by evolutionary pressure. Asexual, fungus-cultivating ants show genetic evidence of vertical transmission of fidelity through their partners, even though external factors play a major role in maintaining fidelity. It is not unusual for cultivars to switch between ant's species due to factors such as vertical transmission.[5] It is not uncommon for cultivars to switch between species of ants, making vertical transmission less important than environmental factors in maintaining fidelity.[6]

Mating and colony foundation

Approximately three years after the colony was created, the queen lays eggs which produce female and male alates, the reproductive ants.[7] Winged males and queens take their nuptial flights high in the air after stuffing some of the fungus' mycelia into their cibariums before leaving the nest to mate. After mating, every male ant die, but their sperms remain viable in the spermatheca, or sperm bank, of their mate, which means that many ants continueto father offspring for years after they die. Some species, such as *Seriomyrmex* and *Trachymyrmex*, mate with only one male, while others, like *Atta sexdens*, mate with as many as eight or ten. Queens cast off their wings after mating flights and begin their descent into the ground, digging a small chamber with a narrow entrance. The fungus wad begins to grow fresh mycelia after three days and the queen has laid four to seven eggs. Within a month, the colony is surrounded by eggs, larvae, and pupae, all feeding on the growing plants. In addition to fertilizing the garden with fecal liquid, the queen catabolizes her wing muscles and fat reserves in order to gain energy by consuming 90% of the eggs she lays.[8]

Farming and gardening

Among attune ants; most of the fungi they farm are from the genera *Leucoagaricus and Leucocoprinus* of family *Lepiotaceae*, though variation occurs among members of the tribe. Few species like *Cyphomyrmex rimosus* cultivate yeast. Although *Lepiotaceae* have been domesticated by lower attines recently, it was previously believed that the culture is transmitted only by vertical transmission from colony to queen. Some species of *Cyphomyrmex* and rarely some species of *Acromyrmex* transfer by lateral transmission thereby invading another colony's garden. As foragers enter the nest chamber, leaf fragments are dropped there. Workers, cut those fragments into segments 1-2 mm wide. By adding fecal droplets and kneading them, these fragments are crushed by smaller ants and molded into damp pellets. The pellets are added into a bigger pile. After plucking loose strands from dense patches of fungus, smaller workers plant them on top of the newly formed pile. Keeping up the garden is the responsibility of the smallest workers, the minims, who skillfully prod the piles with their antennae, lick the surface, and poke out spores and hyphae of undesirable mold.[9]

Conclusion

By developing enzymes that allow ants to access nutrients in the fungal mass, fungi have evolved to become more striking to ant species. Fungal cultivars lost a succession of genes allowing them to decompose a wide variety of substrates during the transition from lower agriculture to higher agriculture. It appears that attine ants propagated their colonies through vertical transmission, and were no longer able toreproduce sexually with their nonsymbiotic partners or lower-attine counterparts at the end of their allopatry. Due to the key role played by fungus-growing insects in the fungus garden, it makes sense to suppose that individual-level or group-level mechanisms evolved to prevent disease outbreaks in the garden, which constitutes an important characteristic of their social immunity. In order to protect the fungus gardens from infective pathogens, leaf-cutting ants use a variety of chemical and behavioural mechanisms. To protect themselves against entomopathogenic microbes, ants use secretions from their metapleural and labial glands, known for their fungicidal, bacteriostatic and fungistatic activity. As well as inhibiting the development of recurrent antagonistic microbes by applying gland secretions onto the surface of a fungal garden.

There has been a great deal of success in the fungus-growing ants' symbiosis due to communication between ants and fungi and their ability to detect and recognize pathogens. Future research should examine the evolution of these mechanisms across the attine ant lineages, including ant-garden communication and defensive strategies. In addition, it remains unclear whether defensive responses are intended to combat specific pathogen genera or species and whether the incidence and germ-free behaviours of such responses would differ. Our understanding of social immunity in leaf-cutting ants has only just begun, and there is still a long way to go until we can draw a complete picture of a microbe's encounter and defense.

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Conflicts of interest

The author declares no conflicts of interest.

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