FUNGAL AGRICULTURE AND ENGINEERING IN ANTS.

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Apart from humans only a very few other animals such as the macrotermitine termites, some wood boring beetles and the ants of the tribe Attini, have achieved the necessary sophisticated techniques to culture and grow fungi.

Attini ants are mostly found in the tropical parts of Mexico and Central and South America where they are the dominant herbivores. The *Atta* (the so-called parasol ants) are unique in that they collect portions of fresh leaves and flowers. Having a fungus carry out their initial digestion allows them to escape the effects of plant defensive chemicals, exploiting a wide range of plants, including most crop species making them of major economic significance to Latin America.

All *Atta* species appear to have the same colony life cycle. Prior to the nuptial flight the queen puts a small piece of the nest fungus mycelia into a special body chamber. After the nuptial flight, the queen casts off her wings, excavates a little nest in the soil, and deposits the mycelia onto the floor. By the third day the mycelium has begun to grow and the queen has laid the first few eggs. At intervals of about an hour she tears out a small piece of mycelia, and deposits onto it a drop of faecal liquid, then carefully replaces the mycelia. She appears not to consume any of the fungus subsisting entirely on her own catabolizing fat and redundant wing muscles. After the first month the eggs are embedded in a mat of actively growing fungi.

The first workers emerge after 40 to 60 days, feeding themselves and the larvae on the fungus while the queen stops attending the brood and fungus,
becoming a virtual egg-laying machine.

The part of the fungus that is plucked and eaten by the ants are the tips of the hyphae that produce strange ellipsoid swellings, about 30-50 micrometres in diameter; termed gongylidia. The structures are rich in glycogen, in a form easily assimilated by the ants, and hydrolases, while the mycelium itself has carbohydrates, free amino acids, protein-bound amino acids and lipids.

One of the major problems of the attine-fungus symbiosis is the identity and biology of the fungus. The sporophores necessary for taxonomic diagnosis are presumably prevented by the chemicals generated by the ants, nevertheless the chance discovery of sporophores growing from abandoned *Acromyrmex* nests allowed them to be placed in the Basidiomycete family *Agaricaceae*, initially named as *Rozites gongylophora*, subsequently transferred to *Leucocoprinus gongylophora.*

Interestingly, the ants have domesticated a number of independent fungal cultivars, a process that appears to be ongoing, perhaps in response to a pathogenic mould, in the genus *Escovopsis*, isolated only from the gardens of fungus growing ants This mould reduces growth of the fungal garden, overgrowing and killing the fungus and thus the colony. Also to combat the growth of this pathogenic mould the ants have entered into a mutualistic association with the filamentous bacteria *Streptomyces* (actinomycete) that is carried on specialised regions of the ant's cuticle and produces a specific antibiotic activity that suppress the mould.

The bacterium appears to be a third mutualist within the ant-fungus-bacterium symbiosis. The use of antibiotic producing bacteria to manage pathogens attacking their fungal food supply mimics the treatment of diseases by humans with antibiotics, although the ants clearly predate human use by many millions of years.

Ants are usually nectar feeders, predators and scavengers; their entire digestive system is geared to this dietary commitment. They are ill suited to be pseudo-herbivores. The leafcutter ant-fungus symbiosis has allowed the ants to exploit an energy resource otherwise unavailable to them yet retain their original physiology.

Yet undoubtedly, the most remarkable thing about these unique ants is that they have changed their social habit from the usual hunter-gatherer life-style of ants to that of an agricultural mode.

Another of these interesting fungus-insect partnerships is the unique relationship of the European ant, *Lisius fulginosis,* sometimes called the 'shining black ant', with the fungus *Cladosporium myrmecophilum* (Deuteromycotina), (Gr. *klados,* a branch; hence branched spore chains.)
This fungus nourished with sugars collected by the ants from aphids, grows only in the walls of their nests, reinforcing them structurally.
The ants build their nests in large cavities in the soil and tree trunks, using small bits of wood, dry vegetable matter, and soil, bound with the sugars from the aphids. Throughout the mixture of loosely packed material grows the hyphae of the fungus to reinforce and bind the walls, much as does the steel reinforcement used in buildings. The nest, called a 'carton nest', has slender walls, a highly partitioned internal structure and generally fills most of the cavity.
Nest construction is divided between four castes of ant, based on age; the two oldest castes for material supply, the two youngest castes construct the nest. The oldest ants collect the solid materials, while the next younger collect, in their crops, the sugars from the aphids. The materials are delivered, inside the nest, to the younger constructor ants. The third caste of ants coats the solid materials with the regurgitated sugars, depositing the now wet material onto the edge of the freshly made carton wall. The fourth caste remove old material from the lower parts of the wall and put it on the upper new edge, in the process transferring mycelia into the new nutrient rich carton wall. The ants do not consume the fungus as food, but continuously housekeep by mowing the mycelium, otherwise the fungus quickly over-runs the nest.
The symbiosis benefits are clearly identifiable; the fungus is provided with nutrients and a warm, moist environment, while the ants construct a large thin walled, fungus reinforced, capacious nest, in a protected space, using a relatively small amount of material, which is eminently suitable for housing a large colony, while the overall energy necessary for the construction of the nest is reduced.
Although the ants do forgo the sugary nutrients, the energy diversion for the fungal reinforcement allows the walls to be thinner in section, maximising the living space. To build the same size nest without the fungal reinforcement, the nest walls would need to be thicker in section, requiring greater energy expenditure for the collection of the larger quantity of materials as well as for the construction of the nest reducing the space available to the colony and hence the total size of the colony that could be housed.