Fungus-growing ants selectively cultivate their crops

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Ants: Ever since agriculture evolved ca 10.000 years ago, plants have been artificially selected to become the fast growing and highly productive varieties we know today. However, humans were not the first to see merit in cultivating their own food, as ants have been doing this for 50 million years. A lineage of South-American ants collect leaves and recycle their own feces to manure a fungus garden for food. New research shows that these ants have an evolutionary history of improvement of their fungal crops.

A joint effort by researchers at the Universities of Copenhagen and Lund has produced a reconstruction of how fungusgrowing ants have stepwise improved their clonal crops into a robust and superbly efficient farming system. The results, published today in the prestigious journal *Nature Communications*, show that reliable delivery of some enzymes and vital amino acids in the fungal food explains that the ant farmers have lost the ability to produce these compounds themselves.

Leaf-cutting ants and fungi in close collaboration

Leaf-cutting ants use a broad range of fungal enzymes to degrade harvested leaf fragments in what appears to be an optimal joint venture with sophisticated division of labor. The fungus produces clusters of inflated food packages for the ants. These symbiotic organs provide carbohydrates, lipids, fungal enzymes and vital amino acids and satisfy all the nutritious needs of the ant farmers and of their brood, which also eat garden-fungus. These foodpackage organs evolved ca. 20 million years ago and represented an innovation that allowed today's leaf-cutting ants to evolve truly large-scale farms.

Fungus-growing ants became farmers ca. 50 million years ago, but the first 30 million years they only had small-scale subsistence farms in which they used plant debris to make tiny fungus gardens grow. However, that suddenly changed and from then on developments accelerated.

"Although it took ages of slow natural selection, today's ant farms are ca. 100.000 times larger than those of the first ancestors that invented farming", says Henrik De Fine Licht -the first and corresponding author.

This is comparable to what most modern human agricultural systems have achieved, and it is striking that the scale of environmental effects appears to have increased to the same degree. Not like human farming that uses enormous amounts of water, fertilizer and pesticides, but for the ants the key resource is access to fresh leaves. Their most advanced societies became aggressive herbivores that cause massive defoliation damage in natural ecosystems and human farmland in Latin America.

Slow natural selection versus fast cultural evolution

Human farming practices took less than 10.000 years of cultural evolution to reach today's sophistication, so progress in the fungus-growing ants has been orders of magnitude slower. Doing this "the ant way" also came at the price of complete mutual dependence of each family of ants on a single clonal crop. This life-time symbiotic matrimony allowed the ants to lose an entire amino acid synthesis pathway as it could become outsourced to the fungal crops. However, where specialization in human farming normally increases susceptibility to disease and unfavorable weather, the ant farming symbiosis remained remarkably robust. In fact, they are renowned for having very few serious diseases, which makes it very difficult to control them with environmentally friendly means.

"It is as if the farming ant families and their underground gardens have become single organisms where queen, nurses, foragers, brood and fungus are connected in a huge interaction network. All parties make complementary contributions just like different tissues in a single body. So far studies have only looked at division of labor among the ants, but now we know that fungal organs are also of key significance. No other fungus has evolved such organs because they are only meaningful when you rely on farmers. This is similar to cultivated wheat varieties that no longer drop their seeds because humans only propagated lineages that allowed them to harvest the spikes rather than having to pick up the seeds one by one", says Henrik De Fine Licht.

The study analyses specific signatures of selection on fungal genes and provides new understanding of the genetic and protein adaptations that optimized fungal crop performance. We expect that such insights can inspire our own thinking about clever biotechnological solutions to handle green natural resources.

More information: Henrik H. de Fine Licht, Jacobus J. Boomsma & Anders Tunlid (2014). Symbiotic adaptation in the fungal cultivar of leaf-cutting ants. *Nature Communications*. Published 1 December 2014 www.nature.com/ncomms/2014/141 … /abs/ncomms6675.html

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