

## The True Origin of Agriculture: Credit Goes to the Ants

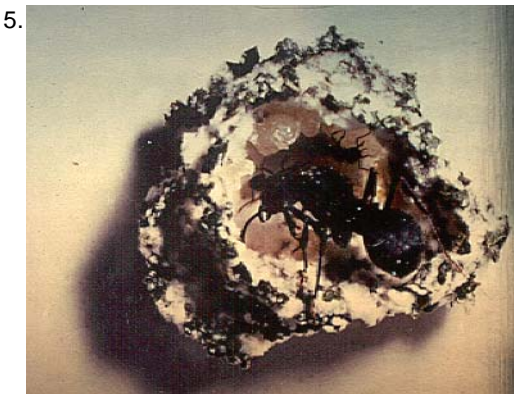
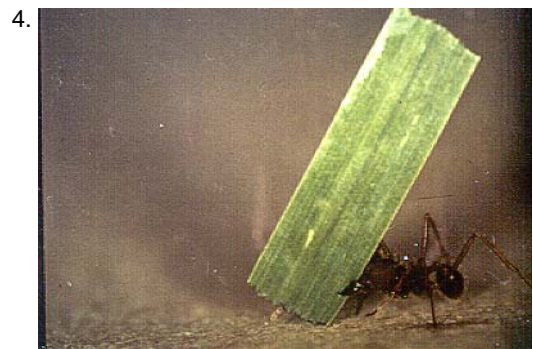
*Raghavendra Gadagkar*

Human agriculture which is believed to have originated some 10,000 years ago has rightly been considered the most important development in the history of our species. Virtually all the plants which we consume today are derived from cultivars that have been bred and modified by humans for thousands of years. There has also been extensive exchange of cultivated crops from one part of the globe to another. While consuming plants and their products, we tend to forget that the cultivation of coffee originated in Ethiopia, that of tobacco around Mexico, tomato and potato in South America, rice in South East Asia and so on. The impact of agriculture on the further development of human societies has been profound – high rates of population growth, urbanization and economic surpluses all of which were pre-requisites for the development of modern civilization.

Impressive as all these are, our achievements are surely humbled by the lowly ants which appear to have invented agriculture, and as we shall see below – a fairly sophisticated type of agriculture – almost 50 million years before we did. Three different groups of insects practise the habit of culturing and eating fungi. They are ants belonging to the tribe Attini, macrotermite termites and certain wood-boring beetles. While the beetles in this group are few and not of com-

parable importance, the fungus growing ants in the new world, and termites in the old world, are ecologically very dominant. With a few exceptions, all fungus growing ants are also leafcutters – they cut pieces of leaves, bring them to the nest and use them as substrate to grow fungi. The ants derive their nutrition only from the fungi so grown and not from the leaves themselves. There are some 200 species of ants which do not know any life style other than fungus farming. Because of their ecological dominance and their insatiable hunger for leaves, leafcutter ants are major pests in the new world. These ants can devastate forests and agriculture alike – they may maintain ten or more colonies per hectare and a million or more individuals per colony. Where they occur, the leafcutter ants consume more vegetation than any other group of animals. Not surprisingly, many Latin American countries have passed national laws declaring leafcutter ants as ‘plague animals’.

Like in the humans, the advent of agriculture appears to have significantly affected the evolution of leafcutter ants. Today the leafcutter ants are among the most advanced and sophisticated social insects. As may be imagined, the process of fungus cultivation is a complicated business. In the field, leaves are cut to a size that is most convenient for an ant to carry them back. In the nest the leaf fragments are further cut into pieces 1–2 mm in diameter. Then the ants apply some oral secretions to the leaves and inoculate the fragments by plucking tufts of fungal



**Figure 1.** A portion of the fungus garden of the leaf cutter ant *Atta sexdens*.

**Figure 2.** Worker ant of *Atta sexdens* cutting a grass blade in Sao Paulo, Brazil.

**Figure 3.** Two workers of *Atta sexdens* cutting grass blade in Sao Paulo, Brazil.

**Figure 4.** Worker ant of *Atta sexdens* carrying a cut piece of grass to the nest in Sao Paulo, Brazil.

**Figure 5.** A founding queen of the leaf cutter ant *Acromyrmex lundii* in Buenos Aires, Argentina with her small fungus garden, eggs, larvae and one newly emerged daughter worker.

**Figure 6.** The surface of a large nest of the leaf cutter ant *Atta vollenweideri* nest in Formosa, Argentina. The distinguished Argentinean social insect biologist Jose Nunez can be seen standing at the edge of the nest.

Photo Credit: Flavio Roces



mycelia from their garden. The ants maintain a pure culture of the fungus of their choice and prevent bacteria and other fungi from contaminating their pure cultures. Growing pure cultures of some of these fungi in the laboratory has proved difficult or impossible. How the ants achieve this remarkable feat remains poorly understood. Not surprisingly, they manure their fungus gardens with their own fecal pellets. When a colony is to be founded, the new queen receives a dowry from her mother's nest – a tuft of mycelia carried in her mandibles. Thus these ants appear to have asexually propagated certain species of fungi for millions of years.

What kind of fungi do these ants cultivate? Do all ants cultivate the same type of fungi? As in the case of human beings, have there been multiple, independent events of cultivating wild species? Like humans, do the ants exchange cultivars among themselves? Until recently it was not easy to answer any of these questions. Today, with the advent of powerful DNA technology, answers to many of these questions can be attempted and this is precisely what Ulrich Mueller, Stephen Rehner and Ted Schultz have recently attempted to do [1]. First they collected 553 samples of fungi from the fungus gardens of 7 genera of ants. Next they compared variable regions in the DNA of each of these samples and also sequenced and compared portions of two genes from 25 free-living and 57 ant-cultivated fungi (for a discussion of how DNA sequences can be compared to

yield phylogenetic inferences, see [2]). Their results suggested that there may have been at least five different independent origins of fungal cultivation by ants, rather than a single event as was supposed previously. Even more interesting, their results suggest that ants occasionally exchange fungal cultivars among themselves so that different nests of the same species of ants may contain different cultivars. Whether the ants deliberately borrow fungal cultivars from their neighbours or whether the horizontal transfers occur accidentally is however not known. But there is good evidence that new cultivars have been added to the ant fungal gardens from time to time.

An obvious reason for our interest in these studies concerns the parallels between human agriculture and ant agriculture. But when modern DNA technology raises the sophistication of our understanding of ant agriculture to this level, the subject becomes interesting in its own right. Of the many new questions that can now be posed, perhaps the most fascinating ones concern the manner in which ants deal with pests interfering with their agriculture and the effect of agriculture (including perhaps 'economic surpluses' thus generated) on the evolution of the ants themselves. We may now expect to see an increase in studies that address these issues – some have already begun to appear in print (see [3], [4], [5] and [6] in Suggested Reading).

On a more sober note, we should not fail to realise that if man had successfully eradi-



cated these 'plague animals', how much poorer we would have been. The attitude we need to take in these matters is best illustrated in the following passage, by Hölldobler and Wilson, in their monumental book, *The Ants* [7]: "Leafcutting ants are among the most advanced of all the social insects. During the past ten thousand years, a mere eyeblink in geological time, these insects have encountered the most advanced product of mammalian evolution from the Old World, *Homo sapiens*. Certain difficulties have arisen from this contact, with the great bulk of the losses occurring on the human side. In order to redress the balance, we need to learn a great deal more about the biology of our adversaries, paying particular attention to the weak points that undoubtedly occur in their complicated social systems. The goal, however, should be intelligent management of their populations and never their complete eradication. Our advantage – and responsibility – lies in the fact that we can think about these matters and they cannot".

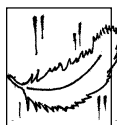
## Suggested Reading

- [1] U G Mueller, S A Rehner and T R Schultz, *The Evolution of Agriculture in Ants*, *Science*, 281, 2034–2038, 1998.
- [2] C B Rao and K C Majumdar, Reconstruction of phylogenetic relationships, *J. Biosci.* 24, 121–137, 1999.
- [3] C R Currie, U G Mueller and D Malloch, The agricultural pathology of ant fungus gardens, *Proc. Natl. Acad. Sci. USA*, 96, 7998–8002, 1999.
- [4] C R Currie, J A Scott, R C Summerbell and D Malloch, Fungus-growing ants use antibiotic-producing bacteria to control garden parasites, *Nature*, 398, 701–704, 1999.
- [5] T R Schultz, Ants, plants and antibiotics, *Nature*, 398, 747–48, 1999
- [6] D M Wilkinson, Ants, agriculture and antibiotics, *Trends Ecol. & Evol.*, 14, 459–460, 1999.
- [7] B Hölldobler and E O Wilson, *The Ants*, Harvard University Press, Cambridge, USA, 1990.

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### Fermat's Last Theorem

*Once upon a time, a judge did muse  
on a question of no apparent use.  
The proof – had it been written  
would've covered France and Britain.  
That would've been the end of the news!*

$X^n + Y^n + Z^n = 0$   
*has given birth to Z [ ρ ].  
I hear now there is a solution  
done by people in collusion  
and one of them is a hero!*

Yrus

