EARTH SCIENCES
Published: 23 June 2023
doi: 10.3389/frym.2023.1194085

RELATIONSHIPS BETWEEN TREES AND FUNGI IN A TIME OF CLIMATE CHANGE

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YOUNG REVIEWERS:

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AGES: 13–14

Fungi form important relationships with trees, in which both the trees and the fungi benefit. Scientists recently discovered that fungi are critical in forests because they help to transfer carbon-containing materials between trees. Previously, no one knew whether these materials were distributed equally between all trees. In our study, we examined the transfer of carbon between trees planted in large containers with forest soil containing their natural fungi. We found that there is an unequal transfer of carbon between trees of different species: some species of trees (such as oaks) transfer more carbon to the fungi and on to trees around them than they receive; and other species (such as pines) receive more than they transfer. Climate change is expected to make it more difficult for trees to survive. In a hot, dry world, carbon exchange between trees may be able to help trees—and possibly entire forests—to survive.

COOPERATION BETWEEN TREES AND FUNGI

Most of the time when we think of fungi, we think of mushrooms popping out of the ground or growing on dead wood in a forest. But mushrooms are only the above-ground part of fungi, also called **fruiting bodies**. We cannot actually see the majority of the fungus because it is underground and consists of thin, white webs that stretch for many meters through the forest soil. These webs are called **hyphae** (Figure 1). Hyphae function as a transportation system to move substances like water and nutrients between parts of the fungus.

FRUITING BODY

The aboveground part of a fungus, which we call mushroom. The fruiting body contains spores (fungal seeds) and can be edible or poisonous.

HYPHAE

The structures making up the main body of the fungus, made of many thin webs found underground. Hyphae can absorb minerals from the soil.

Figure 1

Figure 1

A potted pine tree with mycorrhizal fungi. In the upper part of the soil, you can see the white-colored webs that make up the hyphae of the fungi. In the lower part of the soil, you can see the tree roots [Figure credit: Cahanovitc et al. [1]].

Fungi feed in a variety of ways and they play several roles in the forest ecosystem. For example, the sycamore mushroom feeds on dead plants in the forest soil, helping to decompose them. Another type, called **mycorrhizal fungi**, connect to the roots of trees. The trees and the fungi help each other—the trees give food to the fungi in the form of carbon-containing materials, and in return the fungi give the trees essential minerals from the soil. Additionally, the hyphae of mycorrhizal fungi reach deeper down into the soil than the tree roots can, so they help trees to absorb more water.

MYCORRHIZAL FUNGI

A type of fungi that work together with plants. The fungi receive carbon-containing "food" from the plants, and the plants get water and minerals from the fungi.

This relationship between fungi and trees, in which both organisms benefit, is called **symbiosis**. Each tree can connect to several species of fungi, and each fungus can connect to several species of trees. In this way, mycorrhizal fungi create a network that allows substances to pass between trees in a forest.

SYMBIOSIS

A partnership between organisms, in which both organisms benefit.

CARBON TRANSFER BETWEEN TREES

In 1997, scientists re-examined the relationship between fungi and trees. Professor Suzanne Simard from the University of British Columbia, Canada, discovered that young trees in the forest can transfer carbon back and forth [2]. That is, carbon is not only transferred to the fungi growing around the tree roots, but also to the neighboring trees! Simard hypothesized that the transfer of carbon takes place through the mycorrhizal fungi. Indeed, studies have shown that the more fungi there are connecting different tree species, the more carbon is transferred between them [3]. The studies also showed that the transfer of carbon between trees happens in at least two types of forest: northern forests (called boreal forests) and in forests with a mild climate [4].

TRACKING MATERIALS THAT TRAVEL BETWEEN TREES

To test whether substances pass equally between trees of different species, a group of researchers from the Weizmann Institute of Science grew young trees that are usually found together in the same environment, including pine, oak, cypress, carob, and mastic tree. They grew the trees in containers that simulated the Mediterranean forest where these trees usually grow. The researchers planted various combinations of tree species in each container, and they chose one tree in each container (a different species in each), called the "marked" tree, to receive carbon dioxide (CO_2) gas (Figure 2).

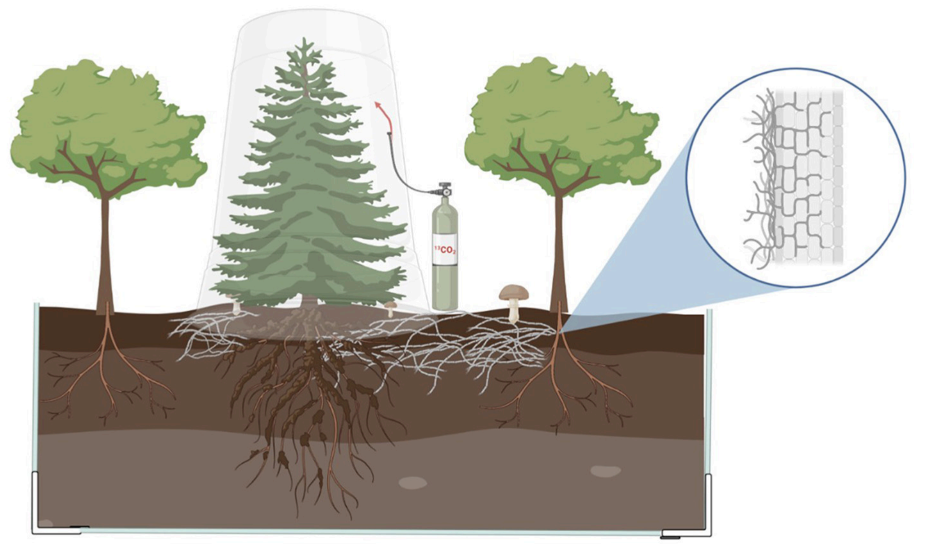

Figure 2

Figure 2

Experimental setup. We planted various species of Mediterranean trees in each container, including pine (center) and oak (sides). In this case, the pine tree is surrounded by a bag and receives CO_2 containing carbon 13, which we can track. The hyphae of the fungus are spread through the ground, attached to two of the trees. The fruiting body (mushroom) of the fungus is seen above the ground. In the circle, you can see a close-up of the hyphae (dark gray) growing between the cells of the tree root (light gray) (Figure created using BioRender.com).

CARBON 13

A specific form of carbon. In nature, 99% of all carbon is carbon 12, and only 1% is carbon 13. Since carbon 13 is so rare, it can be used as a labeling material.

The researchers used CO_2 with a special type of carbon that they could track, called **carbon 13** (Figure 3). The marked trees absorbed the carbon through their leaves and turned it into other carbon-containing compounds. To see whether the carbon reached nearby trees, various parts of the neighboring trees—such as the roots, branches, and leaves—were sampled over a period of 8 months. In this way, the researchers could see whether the carbon given to the marked trees reached the surrounding trees, and which tree parts it went to.

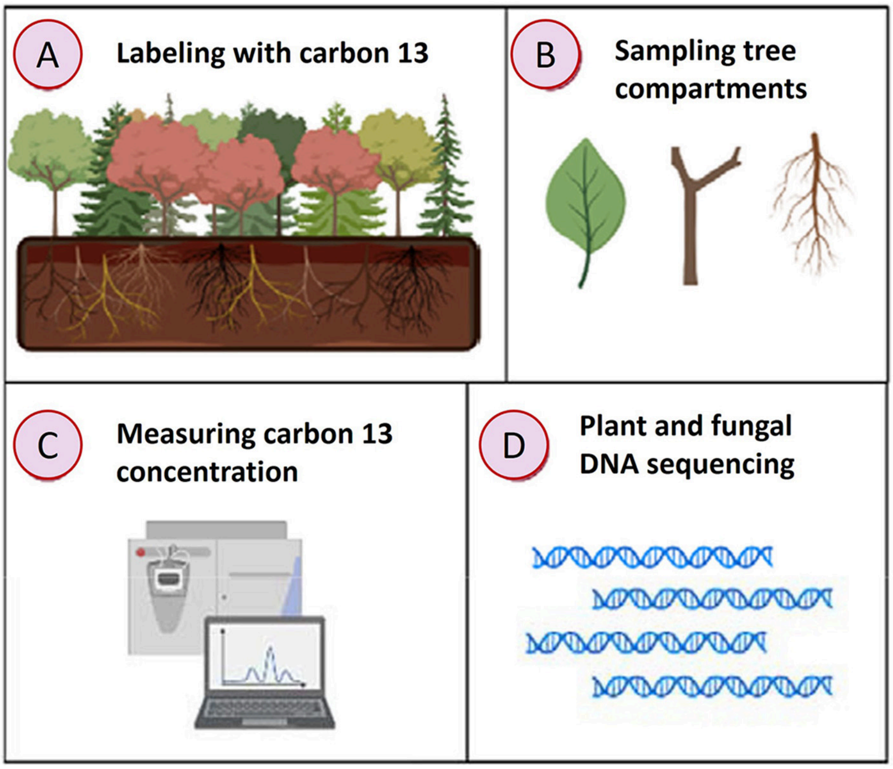

Figure 3

Figure 3

Stages of the experiment. **(A)** Marking certain trees with carbon 13, which we can track, and monitoring the carbon concentrations in nearby trees. **(B)** Sampling various parts of the trees: roots and leaves. **(C)** Measuring the amounts of carbon 13 in the various tree tissues, to examine the passage of materials between the trees. **(D)** DNA sequencing of plants and fungi to identify the types of fungi and tree roots (Figure credit: Source article).

The researchers also used a laboratory technique called **DNA sequencing** to identify which fungi were found around the roots of each of the trees, and they checked to see if there were any common fungi among the trees that seemed to be exchanging carbon. The researchers also sequenced the DNA of the tree roots, to make sure that they were looking at the roots of the correct tree—not an easy task when digging in the ground.

DNA SEQUENCING

A laboratory technique in which the order of the "letters" making up an organism's DNA is determined. That sequence can be used to identify the organism.

DOES CARBON PASS BETWEEN TREES EQUALLY?

The researchers found that carbon moved between neighboring trees, which they expected from previous research. A Mastic tree received carbon from cypress and carob trees. An oak tree transferred carbon to a pine tree. Cypress, carob, and pine trees transferred carbon to trees that were members of their own species. The carbon passed between trees that shared a common fungus with the marked tree that originally received the CO_2. In other words, carbon was shared even between neighboring trees that were very different from each other, provided that shared the same mycorrhizal fungi.

The researchers also discovered that carbon passes unequally between trees. That is, some tree species, such as cypress and carob, often receive more carbon than they give. Other species, such as oak, mainly give carbon to the network, and receive back less carbon from the trees around them. The researchers noticed that there was more carbon in the roots of oak trees than in the roots of the other tree species. They hypothesized that the transfer of carbon may depend on the amount of carbon in the roots. That is, trees with more carbon in their roots give carbon to fungi and on to trees with less carbon. This could explain why a tree with a lot of carbon in its roots (such as the oak) mainly gives carbon, while trees that have less carbon in their roots mainly receive carbon.

It is important to remember that this experiment was done using only a small number of trees and a small amount of carbon. In other experiments conducted with the help of an advanced computer model, researchers discovered that 4–29% of the carbon in the roots of the trees around a marked tree came from that marked tree. Carbon can also pass between trees directly from the ground, but this is slow and inefficient.

MYCORRHIZAL NETWORKS IN A TIME OF CLIMATE CHANGE

Some trees in a forest function well, while others struggle to survive after being exposed to extreme conditions like drought or heat or after being attacked by insects or diseases. Since the movement of carbon between trees is not equal, mycorrhizal fungi can transfer carbon from strong trees to weaker trees. This sharing of resources might help the weak trees to survive, and maybe even to grow stronger.

Over the past 200 years, human activities have released greenhouse gases into the atmosphere, which is causing climate change. Many trees are experiencing increasing pressures like frequent droughts; longer, hotter heat waves; and dangerous flooding. The results of this experiment tell us that the sharing of resources between trees might help to create a healthier forest ecosystem—one that has a better chance of surviving these extreme climate events. A healthy forest ecosystem provides many benefits to humans, such as purifying water, creating oxygen, and even regulating the climate to moderate the rate of climate change.

WHAT IS NEXT?

More research is needed to determine whether carbon transfer between trees can really help to keep trees and forests healthy. In a new experiment, researchers are creating a system of strong and weak trees growing side by side. Trees need sunlight to absorb CO_2 in photosynthesis, and thus shading over several months is being used to weaken some trees. The researchers want to see if mycorrhizal fungi connecting these trees can transfer carbon from strong trees to support weak trees. Such an experiment can tell us about the role of underground mycorrhizal networks in forests. In a time of climate change, one of the oldest symbiosis systems might come to the rescue.

ORIGINAL SOURCE ARTICLE

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SUBMITTED: 26 March 2023; **ACCEPTED:** 07 June 2023;
PUBLISHED ONLINE: 23 June 2023.

EDITOR: Idan Segev, Hebrew University of Jerusalem, Israel

SCIENCE MENTORS: Racheli Yaacov

CITATION: Rapaport A and Klein T (2023) Relationships Between Trees and Fungi in a Time of Climate Change. Front. Young Minds 11:1194085. doi: 10.3389/frym.2023.1194085

CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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We are 8th grade students at the Bar-Ilan Ulpanit in Netanya. During the year, we took part in the “Frontiers” project at school, in which we researched different fields of science and reviewed an entire article. We are curious, and love science and innovation.

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I am a master’s student at the Weizmann Institute of Science in Rehovot, Israel. As part of my studies, I am researching how fungi connect trees. I graduated with a bachelor’s degree in plant sciences and agronomy. I would like to continue my research, and try to apply the science I am involved in to fight climate change and help farmers produce more food. *alonephraim2@gmail.com

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