# Belowground carbon transfer across mycorrhizal networks among trees: Facts, not fantasy

Tamir Klein, Ido Rog, Stav Livne-Luzon, Marcel van der Heijden, Christian Körner



# Mycorrhizas are fungal associations between plant roots and beneficial fungi



In forests, some of these belowground associations can include more than one tree, creating a common mycorrhizal network (CMN)



Klein et al. (2016), van der Heijden (2016)

## Research on common mycorrhizal networks sparks our imagination





### Enough is enough...

#### nature ecology & evolution

Perspective

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#### Positive citation bias and overinterpreted results lead to misinformation on common mycorrhizal networks in forests



Viewpoint

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Justine Karst <sup>1</sup>, Melanie D. Jones <sup>2</sup> & Jason D. Hoeksema <sup>3</sup>

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Re-examining the evidence for the mother tree hypothesis – resource sharing among trees via ectomycorrhizal networks

#### CellPress

# Trends in Plant Science

Opinion

# Mother trees, altruistic fungi, and the perils of plant personification

David G. Robinson <sup>(b)</sup>, <sup>1,\*</sup> Christian Ammer, <sup>2</sup> Andrea Polle, <sup>3</sup> Jürgen Bauhus, <sup>4</sup> Roni Aloni, <sup>5</sup> Peter Annighöfer, <sup>6</sup> Tobias I. Baskin, <sup>7</sup> Michael R. Blatt, <sup>8</sup> Andreas Bolte, <sup>9</sup> Harald Bugmann, <sup>10</sup> Jerry D. Cohen, <sup>11</sup> Peter J. Davies, <sup>12</sup> Andreas Draguhn, <sup>13</sup> Henrik Hartmann, <sup>14</sup> Hubert Hasenauer, <sup>15</sup> Peter K. Hepler, <sup>7</sup> Ulrich Kohnle, <sup>16</sup> Friederike Lang, <sup>17</sup> Magnus Löf, <sup>18</sup> Christian Messier, <sup>19</sup> Sergi Munné-Bosch, <sup>20</sup> Angus Murphy, <sup>21</sup> Klaus J. Puettmann, <sup>22</sup> Iván Quiroz Marchant, <sup>23</sup> Peter H. Raven, <sup>24</sup> David Robinson, <sup>25</sup> Dale Sanders, <sup>26</sup> Dominik Seidel, <sup>27</sup> Claus Schwechheimer, <sup>28</sup> Peter Spathelf, <sup>29</sup> Martin Steer, <sup>30</sup> Lincoln Taiz, <sup>31</sup> Sven Wagner, <sup>32</sup> Nils Henriksson, <sup>33</sup> and Torgny Näsholm<sup>33</sup>

#### ...But:

### Don't throw the baby out with the bathwater!



# We argue that factual evidence about belowground C transfer across CMNs is solid and accumulating

DNA-stable isotope probing to showed <sup>13</sup>C in the DNA of specific mycorrhizal species colonizing roots of donor and recipient saplings, growing in forest soil under natural conditions



# In addition, the label was found not on roots only, but also in stems of mature trees in the forest



# (1) Why is CMN-C transfer so elusive?

- Some labeling experiments detect CMN-C transfer, others do not
- Labeling intensity is too low to detect an otherwise small C flow (high labeling material costs)
- Chances are meager to collect the specific root with specific mycorrhizal fungi at the exact time of C transfer
- The mycorrhizal community of mature trees differs on every root
- Trees allocate different amounts of C to varying roots according to soil niche, microbial community, and other root trait parameters



Cahanovitc et al. (2022)

Pair 1

- (2) How important are alternative transfer pathways? respiration, exudation, turnover, mass flow, assimilation, and redistribution by soil biota
- These pathways probably can never be completely ruled out
- However, C flow through fungal mycelium is much more efficient than through bulk soil
- Diffusional mass flow in unsaturated soil is in the magnitude of m month<sup>-1</sup>; temporal dynamics (Avital et al. 2022)
- Exudates rarely travel more than a few mm in soil without active transport (Kuzyakov et al. 2003).
- Lack of label transfer to plants hosting other mycorrhizal types, nor to saprotrophic fungi (Klein et al. 2016)





Avital et al. (2022)

# (3) What is the significance for trees?

- C transfer is typically small compared to autotrophic C assimilation, making it less likely to have a direct impact on the recipient's growth
- The significance of the CMN-C transfer is probably more nuanced, e.g., in providing C for osmoregulation (Sapes et al. 2021)
- Trees that may benefit from it, are those limited in C source (Livne-Luzon et al. 2024)





(4) How can we explain the counterintuitive C transfer from fungus to the recipient tree? Is it physiologically feasible against the hexose gradient?

- When the recipient tree is subjected to heavy shading, the roots of the recipient tree may experience C depletion (Sapes et al. 2021), reversing the hexose "gradient" from fungi to roots
- C has been shown to transfer to host trees along with N, most likely in amino acids (Teste et al. 2009)



(4) How can we explain the counterintuitive C transfer from fungus to the recipient tree?

- Myco-heterotrophic plants that lack chlorophyll obtain C from other plants by parasites on CMNs throughout their lifespan (Leake 2005)
- Almost all orchids obtain C and nutrients from their mycorrhizal symbionts, before a green and autotrophic plant emerges (Cameron et al. 2008).



(5) What is the benefit to the fungus? An evolutionary advantage should exist for fungi to maintain diversity of tree hosts and hence C sources

- C transfer takes place between different, unrelated tree species sharing mycorrhizal species, including dual mycorrhization (Avital et al. 2022)
- in a mixed Mediterranean forest, tree species diverge in their phenologies and functions (Rog et al. 2021)
- Without a mechanism for tree-directed C transfer across CMNs, it is most probably driven by the fungi, rather than by the trees



#### Ido Rog

PhD student ido.rog@weizmann.ac.il Nella and Leon Benoziyo Building

Rog et al. (2024)



# Summary

- Need for more experimental studies to visualize that a single mycorrhizal mycelium interconnects different trees and to assess when and how much C is moving from one tree to another
- However, there is sufficient evidence that trees in forests are connected by a CMN and transmitting C among themselves, and this can lead to new management practices







## Thank you! Questions?

The next few years might shed new light on how CMNs and C transfer may affect forest resilience, as the field is rapidly evolving





Stay tuned to the Weizmann Tree Lab!