These ratios of the parts of the AMF can help indicate the effectiveness of the symbiotic relationship between the plant roots and the fungi.

The data collected for “02_Dataset_Raw” is used in the results section, AM fungi colonization, and Figure 1.

Vesicles Colonization

Job: storage

Vesicles: store lipids and other nutrients and can provide resources to source plants in times of insufficiency

- High vesicles: AMF are actively storing nutrients/dormancy (does not mean that symbiosis is not doing well, just inactive or responding to stress), well-established symbiosis,
- Low vesicles: AMF are actively exchanging nutrients (could lead to increased arbuscular formation?), poor environmental conditions for symbiosis (stress)
    - Stress can lead to high or low vesicles quantity depending on if the plant is still investing into the MF or just focusing on surviving itself

Vesicles quantity **does not necessarily/directly tell us how effective the symbiosis is** (nutrient exchange does not occur here), but can help us infer when compared with arbuscule quantity

Arbuscule Colonization

Job: nutrient exchange site

Arbuscules: nutrient exchange occurs here, primarily phosphorus and nitrogen, in exchange for the plants carbon compounds

- High arbuscules: Active nutrient exchange, well-established symbiosis, plant is benefitting from symbiosis, soil conditions are favorable for fungal growth
- Low arbuscules: weak symbiosis, potentially due to environmental stress or high phosphorus/nitrogen availability, so the plant does not need to AMF at this time

Overall, **arbuscules** are the best indicator of effectiveness of symbiosis

Hyphae Colonization

Job: nutrient transport, soil exploration/colonization

2 main groups of MF

Septate endophytes are a type of fungal endophyte that have cross walls called septa dividing its hyphae into separate compartments

Hyphae quantity also does not directly tell us how effective the symbiosis is, but can help us understand how long a symbiosis has been established and how active it is

- Which indirectly can tell us how effective the symbiosis is

High (total) hyphae: high nutrient foraging capacity of MF, long-established symbiosis
Low (total) hyphae: high nutrient availability in soil (plant does not need MF help obtaining which can lead to), low plant investment in symbiosis, low soil nutrient

Aseptate endophytes do not have the cross walls (septa) and their hyphae are long and continuous

- Aseptate endophytes: lacking cell wall in hyphae
    - Since they lack the cell wall, nutrients are able to move more efficiently through the hyphae
    - Hyphae within plant roots of majority of vascular plants is aseptate fungi, intra and inter cellular
    - *Glomeromycota*
- Septate endophytes: has cell wall in hyphae
    - Since they have the cell wall, more specialized and compartmentalized acquisition and movement of nutrients, specifically nitrogen, to specific areas
    - Found in ectomycorrhizae
    - Less common than aseptate endophytes
    - *Ascomycota, Basidiomycota*

“Based on the anatomical aspect, root colonization ability of the fungus at intercellular spaces or inside the cells, the mycorrhiza are classified into two main categories: endomycorrhiza and ectomycorrhiza where endomycorrhizae are further categorized into orchid, ericoid, and arbuscular mycorrhizae (Smith & Read, 2010).”

Ratios

- High arbuscules = active plant/AM symbiosis
    - Expect low vesicles
    - Expect high hyphae
- Low arbuscles = inactive symbiosis
    - Expect low vesicles
    - Expect low hyphae
- High vesicles = potentially inactive symbiosis, storing
    - Expect high arbuscules
    - Expect high hyphae
- Low vesicles = potentially actively exchanging nutrients, not storing
    - Symbiosis is well established
    - Expect high arbuscles
    - Expect ___ hyphae
- High Aseptate Hyphae = highly efficient transport, but not necessarily high arbuscules, but works very well together, high phosphorus in soil

- High Septate Hyphae = low nitrogen in soil, working hard to acquire it for the plant, would expect low vesicles?

More Specific Ratios

- **High arbuscule, low hyphae**: High efficiency symbiosis
- **High vesicle, low arbuscule**: storage phase, low nutrient transfer
    - Plant is potentially under high stress, about to enter dormancy, or there is an imbalance in ratio
    - Not necessarily inefficient
- **High hyphae, low arbuscule**: highly colonization and establishment in soil, yet low nutrient exchange
    - Potentially early-stage symbiosis
    - Low efficiency
    - Plant investing low amount of carbon into AM

Conclusions

Just looking at the quantity of 1 part of the AMF, arbuscule, vesicle, or hyphae, in isolation is not able to accurately indicate the efficiency of a symbiotic relationship between a plant and its MF. To best assess mycorrhizal effectiveness, you will need to consider arbuscule, vesicle, and hyphae quantity together.

Moving Forward

How do I want to quantify these ratios?
How do I want to depict these ratios in relation to each other to shed new light on the data this team already collected?
How does soil horizon impact symbiosis in plants and AM fungi? Which horizons have shown greatest or least symbioses and why?

Sources:

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Smith, S E. *Mycorrhizal Symbiosis.* New York, Academic Press, 2008.