SUPER FEEDING

DO MYCORRHIZAE HAVE A ROLE IN HYDROPONICS?

The seemingly magical properties of mycorrhizal fungi (aka 'mycorrhizae') are already fairly well known to soil growers. This special "root fungus" forms a mutualistic relationship with the roots of many plants, allowing them to access more water and nutrients. Mycorrhizae effectively extend the reach of the roots by forming a mycelial network that is able to extract tightly bonded water and nutrients (particularly phosphorus and iron) and translocate them back to the plant. The plant, in turn, feeds the root fungus with carbohydrates. Everybody's happy - it's mutual after all!

Ok, so that's soil. But what about hydroponics? Nutrient manufacturers remain divided on the issue. Some recommend a completely sterile environment. That means no bacteria (beneficial or otherwise) and no friendly fungi. Why? Proponents of sterile growing environments argue that in hydroponics the grower is supplying all the nutrients their plants need in a directly accessible form and question the need for little 'fungi helpers' to assist in nutrient assimilation. (In hydroponics, all the nutrients are supplied in ionic, or directly accessible, form.) Similarly, the roots shouldn't have to go out in search of water in hydroponics as it's being provided in abundance. However, recent studies have shown that mycorrhizae can help plants uptake mineral-based nutrients too, promote with root branching, and massively extend the active feeding capacity of the feeder root tips.

Sound interesting? We thought so! So we asked mycorrhizae experts Mike Amaranthus PhD and Josh Eagan BS to give us the low-down on how this special root fungus behaves in a non-soil environment.

Fungus has a bad name going back a long time. The ancient Romans had a legend regarding a malicious boy who tormented a fox by tying wheat straw to its tail and then setting the straw on fire.The Roman god Robigus was so irritated that he penalized humanity with wheat rust, the fungal disease that leaves a farmer's field looking as though it has been burned. For hundreds of years afterward, the Romans sought to pacify Robigus through sacrifices of dogs and cows with the misfortune of being born with rust-colored fur.

Modern hydroponic growers sacrifice too, increasingly by sacrificing plant quality and profits to prevent damage from a host of fungal "fiends" with names like black rot, club root, sclerotina blight, wire stem, sudden death syndrome, brown spot, and charcoal rot. Opportunities for using beneficial fungi as "friends" exist for the grower as well. The best documented friendly use is mycorrhizal fungal inoculum for improving plant nutrient uptake, plant quality, yields, and disease resistance.

THE FUNGUS FIEND

Most growers blame their nutrients when things start going horribly and unexplainably wrong. Big mistake! Pythium and phytophthora are two of the most common fungal diseases that can affect indoor growers, and they are not easy to spot until well advanced. Pythium-caused root rot is a real problem in hydroponic systems and is becoming increasingly common.

Pythium is a waterborne fungus and recirculating hydroponic systems provide it with an ideal environment in which to live and breed. Plants can survive and grow with high levels of pythium spores in the nutrient solution. The fungus, however, will restrict the root system. A sudden rise in temperature will find the plants unable to increase their uptake of water and they will wilt. For many growers this is the first sign that pythium is active in their system. Damping-off caused by pythium affects growers growing in flats or in the propagation of cuttings. Damping-off can attack and topple plants in just a few days. The lower stem becomes constricted and dark brown near the growth media's surface, a symptom called wire-stem. The hydroponic grower can encounter pythium at any time and, if he is unprepared, he may well lose his crop. Pythium root rot can be caused by several different species of the fungal genera pythium.

Phytophthora, the notorious fungus that caused the Irish potato famine, causes annual crop losses in the tens of billions of dollars today. Beginning in 1845 and lasting for six years, the potato famine killed over a million men, women and children in Ireland and caused another million to flee the country. Phytophthora, from the Greek phytón ("plant") and phthorá ("destruction"), is literally "the plant-destroyer" that continues to plague a wide variety of crops globally with no effective means of chemical control.

Certain fusarium fungal species are also among the most dangerous root diseases in the world affecting hydroponic growers. There has been a dramatic increase in fusarium infection in the last several decades. The ability of this disease to form toxins that are poisonous to both humans and animals makes it a serious problem. The most visible symptom of these fungal diseases is in the root systems. Roots will begin to go brown and lose their healthy white appearance. As the pathogen spreads, the roots become soft and mushy and there is always a tendency for the plant to wilt in the warmer part of the day.

FIG 1: Pythium affected Hosta plant

FIG 2: What a difference a little mycorrhizal fungi makes! The tomato plant on the left was grown without mycorrhizal fungi, whereas the plant on the right was inoculated with mycorrhizal fungi.

THE FUNGUS FRIEND

We can never purge the world of fungus, of course; nor would we choose to. Fungi represent a kingdom unto themselves, the fifth kingdom in fact. As a taxonomic dominion, kingdom is as high as it gets; animals, plants, bacteria, protists and our fungal friends make up the five.

MYCORRHIZAL FUNGI IN HYDROPONICS - Q&A

Q. I ALREADY USE TRICHODERMA. ARE MYCORRHIZAL FUNGI ANY DIFFERENT?

A. Both are beneficial fungi found naturally in soil. Trichoderma are more for cycling nutrients in the soil and providing protection against soil pests (but you will seldom find it labeled as a pest control) while mycorrhizal fungi help more with nutrient and water uptake and increased root growth. Both combined will promote a very healthy root system overall.The two work together well. Trichoderma help make nutrients soluble. Mycorrhizal fungi can actually take the nutrients up and translocate them into the plant.

Q. HOW DO I SUCCESSFULLY INTRODUCE AND PROPAGATE MYCORRHIZAL FUNGI IN MY HYDROPONIC GARDEN?

A. Mycorrhizal fungi can be mixed directly with soil-less media or added to the nutrient solution directly just like any regular powder supplement. There is a myth that you cannot use mycorrhizal fungi with synthetic / mineral-based nutrients, but this is not true. Mycorrhizal fungi can be used with soil, hydroponics and cuttings. The key benefits in hydroponics are extended root systems (which naturally lead to an increase in yield), not to mention protection against root zone pests and diseases. Mycorrhizal fungi cause roots to branch and form more fine feeder roots that can go after nutrients and minerals.

Imagine miles of mycorrhizae hyphae exploring the nutrient resources! Mycorrhizae in pure water culture is problematic as it is a filament fungi - these cannot take the abuse of an impeller pump as it breaks the fragile fungi up.

Q. SHOULD I FEED MYCORRHIZAE CARBS? (E.G. MOLASSES?)

A. Molasses and other carbs are good for feeding bacteria and other types of fungi. But you don't need to feed the mycorrhizae. That's missing the point. The plant feeds them! It's the exudates from the plant roots that cause the mycorrhizal propagules to germinate. (There are synthetic compounds that cause the mycorrhizae to germinate but they are unnatural, expensive and not commonly available.) You are better off adding products which contain humic acids (organic growers can use high quality organic inputs such as North Atlantic sea kelp) to promote more root exudates (food for the mycorrhizae).

Q. WHAT HYDROPONIC GROWTH MEDIA DO MYCORRHIZAE PREFER?

A. Mycorrhizal fungi can create mycelial networks in soil, coco coir, rockwool and many other inert growth media. They can even survive in a totally aqueous environment, as long as it is properly aerated, but they will not replicate. Mycorrhizae will grow and increase in biomass only once they are attached to a plant root.

Q. WHAT ABOUT MYCORRHIZAL FUNGI AND HIGH PHOSPHOROUS LEVELS?

A. Mycorrhizae fungi spores 'sleep' while levels of phosphorus are high (above 70ppm). They only awaken when levels drop lower than this. This is another reason to establish your mycorrhizae as early on in the plant's development cycle as possible.

Q. WHAT CONDITIONS DO MYCORRHIZAL FUNGI PREFER?

A. Temperature: around 68-73°F is ideal but mycorrhizae can also help your plants tolerate occasional temp extremes.

Moisture: mycorrhizal fungi like to have a good air/water mix to thrive. Too moist or too dry is not ideal. Once again, they will help the plant tolerate any extremes that occur.

pH: it depends on the mycorrhizae species but generally they thrive in 5.5-7.5. Some can tolerate acidic conditions better than others while some like alkaline better than others. Look for products that are made from a blend of different species in order to create a healthy mycorrhizae population that will thrive in varying pH conditions.

Q. WHAT CONDITIONS SHOULD BE AVOIDED?

A. Very high temperatures. (135-140°F will definitely start killing them off but then, at those temperatures, the happiness of your fungi is the least of your problems!) The less chlorine your water contains, the better for both fungi and plants too. However, typical levels of chlorine from municipal supplies should not cause a problem.

Q. WHEN SHOULD I START USING MYCORRHIZAL FUNGI?

A. As soon as possible! It takes less mycorrhizae to colonize a juvenile plant than a larger one. Commercial growers have negated the cost of mycorrhizal fungi with their increased seed germination rates. It takes a couple of weeks to form on the roots after the first inoculation so get the process started right at the

seedling / cutting stage. The trick is to introduce the mycorrhizal fungi spores as early as possible to give them time to establish themselves. This is particularly important if you are growing short-cycle plants.

Q. DO MYCORRHIZAL FUNGI NEED TO BE REINTRODUCED ON A REGULAR BASIS? DO I NEED TO ADD IT MORE FREQUENTLY THAN ONCE WITH EVERY NUTRIENT CHANGE?

A. Best performance is achieved with numerous applications throughout the growth cycle. You can't really overdo mycorrhizae. If there are more roots producing more exudates it will probably help to add more mycorrhizae. But don't bother any later than 2-3 weeks before harvest. It's a waste of time. Your mycelial network should already be established. It won't do any harm to keep using it (and often the instructions on the mycorrhizae product will encourage you to!), but you're just wasting your money! Adding it with every nutrient change won't do any harm either. It's just a question of minimizing waste. A good tip is to mix the fungi in a one gallon jug to get it nicely diluted, then pour it into your nutrient solution. Otherwise the powder can sit at the bottom of the res. The white powder you sometimes see at the bottom of your res is just the carrying agent of the spores, not the spores themselves.

Q. WHAT MYCORRHIZAE PRODUCTS CAN I FIND IN MY LOCAL GROW STORE?

A. You'd best ask down at your store! You'll most likely find a few different brands. The products usually come as a jar of white powder - this is a 'carrying agent' for the spores. If you want to compare products, look for the number of mycorrhizal species per pound and the diversity of species. Oh, and the price!

Q. OK, BUT HOW DO I ACTUALLY USE MYCORRHIZAL FUNGI TO BENEFIT MY PLANTS?

A. Mycorrhizal application is easy and requires no special equipment. The goal is to create physical contact between the mycorrhizal inoculant and the plant root. Mycorrhizal inoculant can be sprinkled onto roots during transplanting, worked into seed beds, blended into loose growth media, "watered in" via existing irrigation systems, added directly to the nutrient solution, applied as a root dip gel or even probed into the root zone of existing plants. Most hydroponic growers simply add the fungi by diluting the powder holding the spores into some water and adding this to their nutrient solution. It's very easy.

Q. DO MYCORRHIZAL FUNGI ACTUALLY GUARD THE ROOTS AGAINST OTHER NASTIES? IF SO, WHICH NASTIES EXACTLY?

A. Yes. Nasties include: rhizoctonia, fusarium, pythium and phytophthora. They can also mitigate the detrimental effects of high salt conditions.

Q. HOW EXACTLY DO MYCORRHIZAL FUNGI GUARD THE ROOTS? DO THEY SIMPLY "CROWD OUT" THE ROOT ZONE OR IS IT MORE COMPLEX?

A. Endo mycorrhizal fungi thicken the cell walls around the root cortex making it harder for pathogens to penetrate. They also compete with pathogens for some of the same food sources. Mycorrhizal fungi help with antibiotic production, armoring of roots with chitin, and control of excess nutrients.

Q. WHAT'S THE DIFFERENCE BETWEEN "ENDO" AND "ECTO" MYCORRHIZAL FUNGI?

A. Endo = has an exchange mechanism inside the root (and hyphae extends outside of the root). Ecto= lives only outside the root. The endo mycorrhizae form with mostly green, leafy plants and most commercially produced plants. Ecto mycorrhizae form with mainly conifers and oaks: more woody plants. Endos are for everything else. In hydroponics, ectos don't even matter. Fruits, veg, flowers ... stuff we love to grow ... they love endo.

Q. ARE THERE ANY DIFFERENCES IN HOW THE HYDROPONIC GROWER SHOULD USE MYCORRHIZAL FUNGI COMPARED WITH THE ORGANIC GROWER?

A. Both types of grower need to get the inoculum near roots. Same product, same application rates. Same number of spores per square foot. Both types of growers can reduce their nitrogen and phosphorus inputs.

Q. DO MYCORRHIZAL FUNGI HELP WITH NUTRIENT EXTRACTION IN A HYDROPONIC ENVIRONMENT OR ARE THEY MORE RELEVANT IN SOIL / ORGANICS WHERE NUTRIENTS NEED TO BE BROKEN DOWN FIRST IN ORDER TO BECOME AVAILABLE?

A. Mycorrhizal fungi are just as effective in hydroponic applications as they are in organics / soil. A main function of mycorrhizal fungi is phosphorous uptake. It's important to have a good colonization and a good mycorrhizal fungi "web" already established before you go into flowering.

Some 100,000 species of fungi have been described scientifically, and experts estimate that over a million remain to be discovered. Fungi have influenced our life in ways we take for granted. For a loaf of bread and a jug of wine we can thank the fungus saccharomyces, which is used in bakers' and brewers' yeasts. For recovery from infection we can thank the common soil fungus penicillium. Serendipity often leads to fungal discoveries. When Alexander Fleming discovered penicillin, he was trying to perfect an antiseptic formula based on nasal mucus. The nasal mucus formulation never did materialize (we can all breathe a sigh of relief!), but his unforeseen discovery of antibiotics changed the world.

Fungi also have a flair for symbiosis, for establishing cross-kingdom relationships that feed the fungus sugars while bestowing upon its partner new powers. Under natural conditions plants live in close symbiotic association with a group of soil organisms called mycorrhizal fungi. These fungi colonize plant roots and extend the root system into the surrounding soil. Estimates of amounts of mycorrhizal filaments present in growth media associated with plants are astonishing. Several miles of filaments can be present in less than a thimbleful of soil.

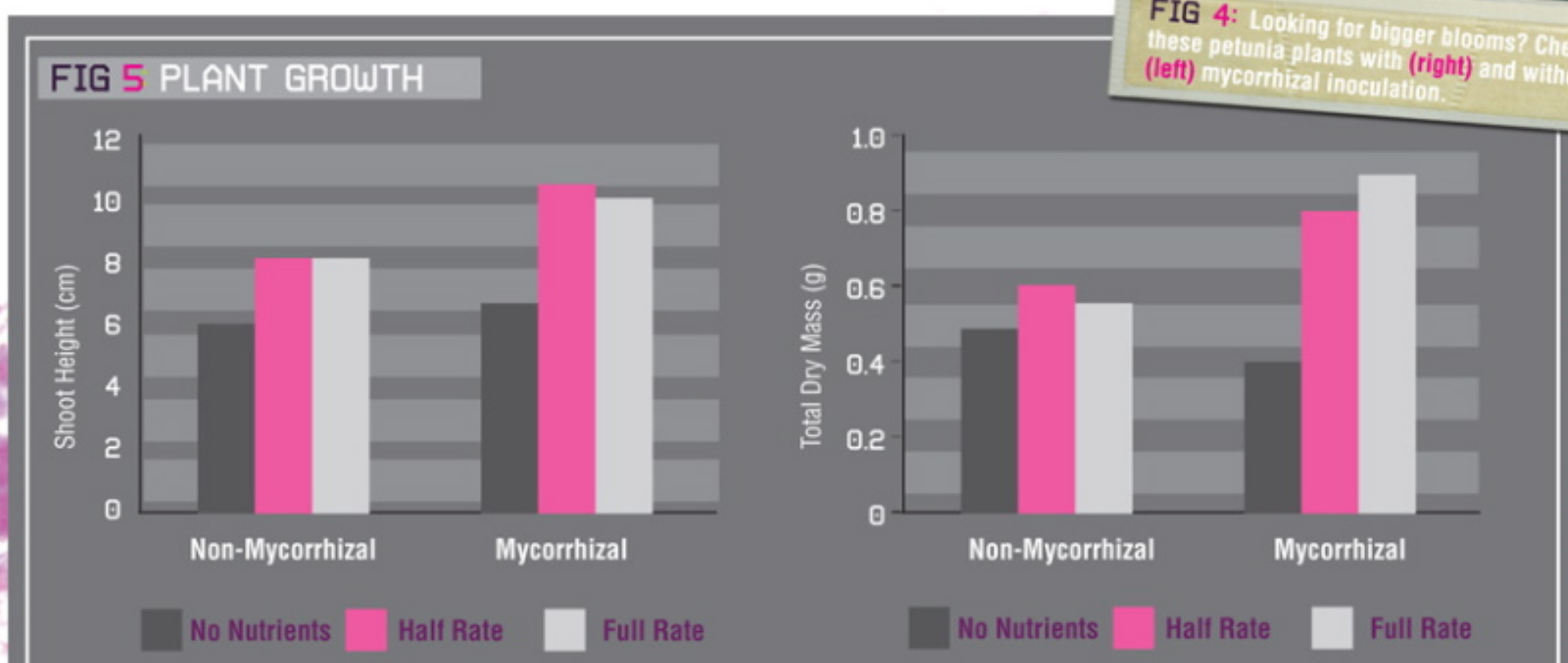
The relationship is beneficial because the plant enjoys improved nutrient and water uptake, disease resistance, and superior survival and growth.

It is this not-so-glorious association between plants and mycorrhizal fungi that keeps the whole show rolling in natural environments and can be an important tool for hydroponic growers.

Approximately 90 per cent of all land plants depend on the mycorrhizal fungi that radiate from their roots and feed humbly on their plant sugars. In return, the fungus delivers nutrients to the plant like phosphorus, calcium, nitrogen, iron and life-giving water. The mycorrhizal relationship is ancient and fundamental. In fact, in natural habitats, the presence of mycorrhizal fungi on the roots of plants is as common as chloroplasts

FIG 3: Mycorrhizal fungal filaments.

FIG 4: Looking for bigger blooms? Check out these petunia plants with (right) and without (left) mycorrhizal inoculation.



Mycorrhizae help plants assimilate nutrients. These charts show the shoot height and total dry mass of mycorrhizal and nonmycorrhizal plants of Rhus integrifolia grown for eight weeks with no fertilizer, with half rate and with full rate of 8N-6P-12K controlled release fertilizer. (Corkidi et al, University of California, Riverside.)

to the leaves of plants. Botanists believe that plants might never have made the leap onto land some 460 million years ago without the assistance of Robigus and his mycorrhizal assistants.

This mutually-beneficial association between fungus and plant provides the fungus with relatively constant and direct access to carbohydrates, such as glucose and sucrose produced by the plant in photosynthesis. The carbohydrates are transferred from plant leaves to the root tissues and then to the fungal partners. In return, the plant gains the use of the mycelium's very large surface area to absorb water and mineral nutrients from the soil, thus improving the mineral absorption capabilities of the plant roots. Mycorrhizal mycelia are much smaller in diameter than the smallest root, and can explore a greater volume of soil-less

FIG 6A: Tomato roots that haven't been inoculated with mycorrhizal fungi.

FIG 6B: Compared to roots that have been inoculated with mycorrhizal fungi.

media, providing a larger surface area for absorption. Also, the cell membrane chemistry of mycorrhizal fungi is different from that of plant roots. The whole length of the mycelia is capable of absorption as compared to just the tips of the roots themselves. Plants grown in sterile soils and growth media often perform poorly without the addition of spores or "propagules" of mycorrhizal fungi to colonize the plant roots and aid in the uptake of soil mineral nutrients.

These mycorrhizal fungi are the best understood of the soil microbe families—and potentially the most useful to growers. Nearly all important crops form the mycorrhizal relationship, with notable exceptions including the mustard family, canola, broccoli, and sugar beets. Mycorrhizae attach themselves to plant roots and grow thread-like hyphae out into the surrounding soil, siphoning amino acids, nutrient molecules and water back to the plant. A grower benefits from mycorrhizal inoculation as it increases the effectiveness of added fertilizer and protects the root system from fungal fiends.

How do mycorrhizal fungi protect roots? The source of disease resistance is probably a combination of factors. The mycorrhizal fungus can present a physical barrier to the pathogenic fungus and/or produce antibiotics that limit the growth of the pathogen. Also, mycorrhizal-colonized plants develop more robust root systems that buffer the plant against the impact of pathogens.

It is also possible that the mycorrhizal fungus stimulates the host to produce chemicals that inhibit the growth of any other fungus on the root. In addition, because the mycorrhizal fungus is so adept at capturing nutrients, there are limited resources available for the growth of the disease fungus. Research has shown that, once a root is colonized by a mycorrhizal fungus, it is more resistant to infection by disease organisms.

INVITING A FRIEND TO DINNER

How do you inoculate mycorrhizal fungi to a hydroponic growing operation? Certain mycorrhizal spores (or "seeds") of the fungus have been selected for their growth-enhancing abilities. The goal is to create physical contact between the mycorrhizal inoculant and the plant root. Generally, mycorrhizal application is inexpensive and requires no special equipment. Growers have at least three options to inoculate with mycorrhizal fungi.

The first method is an incorporation of a granular or powder form of the mycorrhizal inoculant into the growing media before planting. Secondly, the granular or powder inoculant can be placed into soil or soil-less mixes before placing the transplant into the planting hole, or distributed around the root ball after placement. The third option is