Impacts of farm management upon arbuscular mycorrhizal fungi and production and utilization of inoculum

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Introduction to arbuscular mycorrhizal fungi

Arbuscular mycorrhizal [AM] fungi are naturally-occurring soil fungi that form a mutualistic symbiosis with the roots of most crop plants. The plant benefits through increased: nutrient uptake from the soil, disease resistance, and water stress resistance. Other benefits to crop production and agricultural sustainability arising from the symbiosis include increased stability of soil aggregates and increased sequestration of carbon in the soil due to the actions and secretions of the fungi. The fungi benefit through receipt of sugar from the host plant's roots. AM fungi are totally dependent on this source of sugar ("fixed carbon") and are unable to complete their life cycle or grow independently without colonizing a root.

The primary benefit to plant growth arising from the formation of the mycorrhiza (a root colonized by AM fungi) is enhanced uptake of phosphorus. Phosphorus [P] is categorized as a nutrient that is immobile in the soil solution. Roots that are not colonized by AM fungi can take up P only from the volume of soil explored by the root hairs- only 1 mm or so out from the root surface. Roots that are colonized by AM fungi have the "extraradical" hyphae of the fungus (the strands of the fungi that extend out from the root) growing out to upward of 15 cm from the root surface. These hyphae explore a much greater volume of soil, taking up P and transporting it back to "intraradical" structures of the fungi for release to the root cells. This aspect of the symbiosis explains the frequent observation that positive responses of plant growth to inoculation with AM fungi are more likely in low nutrient, especially P, soils. In high nutrient soils, or horticultural situations with frequent nutrient additions, roots may find all the nutrients the plant needs within the root hair zone.

Management and utilization of AM fungi

Given the above-mentioned benefits of the AM symbiosis, optimal utilization of AM fungi is essential for the long term sustainability of agricultural systems. Farmers have two basic options in this regard:

1) better utilize the AM fungus community indigenous to their soils, and
2) inoculate with effective strains of AM fungi.

These two options also basically divide farmers into two groups. Row crop farmers and others that sow seeds of crops in the field are better off managing and utilizing their indigenous AM fungi. Ways that this can be done will be given below. Vegetable and horticulture crop farmers who grow seedlings in a greenhouse prior to outplanting can efficiently use inoculum of AM fungi. This division is readily explained by both practical and biological reasons. Inoculation of field crops, such as corn, requires sufficient inoculum to effectively supplement/compete with the native population. This can become economically infeasible especially considering the low value of each plant. On the other hand, vegetable growers who produce seedlings for outplanting can readily and economically mix AM fungus inoculum into the horticultural potting media for growth of the seedlings.

1. Management of the native population of AM fungi

Many agricultural practices developed to enhance sustainability also have beneficial effects upon AM fungi. Often these could have been predicted with a little prior knowledge of the biology of AM fungi.

a) Use of overwintering cover crops. Inclusion of overwintering cover crops in a crop rotation has been shown to increase the population of AM fungi in the soil. Though this management practice was developed to retard soil erosion, replenish/retain soil nutrients (especially N), control weeds, and add to soil organic matter, it also provides host plants for the AM fungi to colonize and from which to receive sugar for growth and reproduction. Just one cycle of an overwintering cover crop of hairy vetch was shown to increase the AM fungus population in the soil. *Brassica* cover crops, however, are not hosts for AM fungi and although there are other good reasons for using them at times, they will not have this beneficial effect.

b) Reducing tillage. By the time of crop senescence and harvest, a substantial network of extraradical hyphae (the fine threads of the fungi, extending out from the colonized roots) has developed. Subsequent tillage in preparation for sowing the next crop disrupts this network. Broken pieces of AM fungus hyphae are very poor propagules, and are largely incapable of colonizing roots of the next crop plant. No-till is encouraged to retard soil erosion and build soil organic matter, but it also leaves the AM fungus hyphal network intact, allowing for more rapid colonization of the next crop.

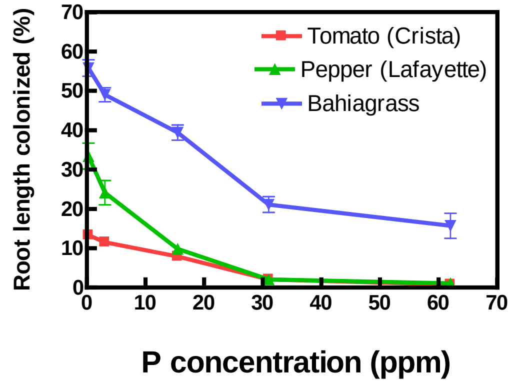
c) Crop rotation. The AM fungus community in an agricultural soil can contain several dozen species, and those that reproduce best on a particular crop are not necessarily those that enhance its growth. This means AM fungi can contribute to the reduced yields characteristic of continuous monocultures. Crop rotations were developed for disease management and their impact upon yield, but they also serve to guard against buildup of populations of ineffective AM fungi.

2. Inoculation with effective isolates of AM fungi

The goal of the use of AM fungus inoculum in the greenhouse is to produce seedlings with established AM fungus colonization, ready to take advantage of the symbiosis upon outplanting, rather than have to wait 1-2 weeks for colonization by the indigenous fungi in the field. Inocula are available commercially either in concentrated form or already incorporated into potting media. Inoculum of the AM fungus community indigenous to the farm can be produced on-farm. Independent of which inocula you use, certain considerations or precautions apply.

a) Inoculate only plants that are susceptible to AM fungus colonization. There are plant families, notably the Brassicas and Amaranthaceae, eg. broccoli and sugar beet, which do not become mycorrhizal (“nonmycotrophic”).

b) Adjust your greenhouse nutrient regime. Plants respond to high levels of nutrients, notably P, by inhibiting colonization by AM fungi. The P level at which this occurs varies by plant, but usually is greater than 10 ppm (see figure). Lower the P and keep other nutrients the same. Growth will likely be about the same.



On-farm production of AM fungus inoculum

Inoculum of AM fungi can be produced on-farm in mixtures of compost and vermiculite with bahiagrass (*Paspalum notatum* Flugge) as the nurse host plant (see resource A(3), below). Briefly, after the threat of frost has passed, plastic bags (7 Gallon "Grow Bags", Worm's Way, Bloomington, IN 47404) are three fourths filled with a 1:4 [volume basis] mixture of screened compost and vermiculite, respectively. One to two hundred cm^3 (approx. 0.5 to 1 cup) of sieved soil (the "starter inoculum"), collected from the surface 10 cm (4 in.) of a field with a diverse plant community, is then added and mixed into the bag. Five *P. notatum* seedlings then are transplanted into the bags. Bags are weeded and watered as needed throughout the growing season, with no supplemental fertilization needed. The roots become colonized and proliferate throughout the bag, as do the AM fungi originally present in the soil. The *P. notatum* host plants are winter killed, and the AM fungi over winter outdoors in the growth medium. The following spring, the compost and vermiculite mixtures, now containing propagules of AM fungi, are thoroughly mixed into horticultural potting media at a rate typically of 1:9 inoculum to potting media (volume basis). Demonstration of this method at cooperating farms has produced an average of 300 propagules cm^{-3} over 40 site years (see resource C, below).

So far, inocula produced by this method have been shown to increase the yield of strawberries, potatoes, peppers, leeks, and sweet potatoes (see resource B, below).

Resources:

A. On the Rodale Institute website:
http://newfarm.rodaleinstitute.org/depts/NFfield_trials/0903/factsheet_mycorrhiza.shtml
http://newfarm.rodaleinstitute.org/depts/NFfield_trials/0604/factsheet.shtml
http://rodaleinstitute.org/2010/a-complete-how-to-on-farm-am-fungus-inoculum-production

B. To find reprints of the research papers that give more details on what was presented, search the ERRC Publications page (accessible on the Internet, does not require VPN): http://wyndmoor.errc.ars.usda.gov/pubs/ and type "Douds" into the author box. (or just contact me directly)

C. See also our article in the Journal of the National Assoc. of County Agriculture Agents: On-farm production of arbuscular mycorrhizal fungus inoculum in compost and vermiculite mixtures: results of on-farm demonstrations and impact of compost microbiological quality. Vol 7, issue 2, Dec 2014.