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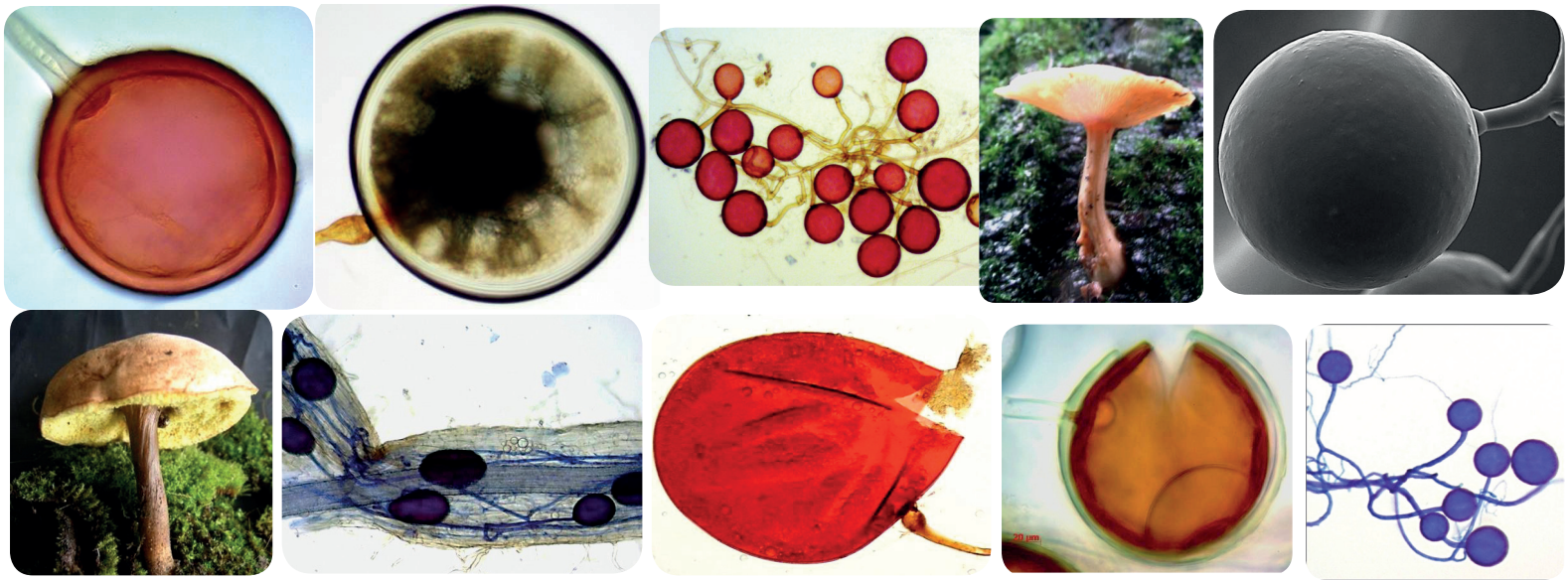

About **TERI**

The Energy and Resources Institute (TERI) is a dynamic and flexible organization with a global vision and a local focus. TERI's focus is on research in the fields of energy, environment, and sustainable development, and on documentation and information dissemination. The genesis of these activities lies in TERI's firm belief that the efficient utilization of energy, sustainable use of natural resources, large-scale adoption of renewable energy technologies, and reduction of all forms of waste would move the process of development towards the goal of sustainability.

TERI's **Mycorrhiza Network**

TERI's Mycorrhiza Network is primarily responsible for establishing the Mycorrhiza Information Centre (MIC), the Centre for Mycorrhiza Culture Collection (CMCC), and publishing *Mycorrhiza News*. The Network helps scientists carry out research in mycorrhiza and promotes communication among mycorrhiza scientists.

Mycorrhiza News

The *Mycorrhiza News* provides a forum for the dissemination of scientific information on mycorrhiza research and activities; publishes state-of-the-art papers from eminent scientists; notes on important breakthroughs; brief accounts of new approaches and techniques; publishes papers complied from its RIZA database; provides information on forthcoming events on mycorrhiza and related subjects; lists important research references published during the quarter; and highlights the activities of the CMCC.

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Research finding paper

Arbuscular Mycorrhiza Fungi in Sustainable Agriculture, Horticulture and Forestry

D J Bagyaraj[a]

Sustainability in agricultural production has emerged as one of the most significant concerns in the 21st century. Sustainability refers to 'successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources' (TAC Secretariat 1989). The current day emphasis is on sustainable agriculture which uses less of chemical inputs and has an adverse effect on soil health and the environment. Thus, AM fungi and other microbial inoculants play an important role in sustainable agriculture. The term 'mycorrhiza' ,coined by A B Frank (1885), literally means 'fungus root' and is a symbiotic association between plant roots and fungi. Though there are different kinds of mycorrhiza, the most common mycorrhizal association occurring in crops that are important in agriculture and horticulture is of the arbuscular mycorrhiza type. These fungi are ubiquitous in soil, occur throughout the world, and form a symbiotic relationship with the roots of most terrestrial plants. AMF occurs over a broad ecological range from aquatic to the desert environment (Bagyaraj 2014a). AMF belong to the phylum *Glomeromycota* which has three classes (*Glomeromycetes*, *Archaeosporomycetes*, and *Paraglomeromycetes*) with 5 orders (*Glomerales*, *Diversisporales*, *Gigasporales*, *Paraglomerales*, and *Archaeosporales*), 14 families, and 26 genera (Sturmer 2012). The commonly occurring genera of AMF are *Glomus*, *Gigaspora*, *Scutellospora*, *Acaulospora*, and *Entrophospora*. In the soil, AMF produce large thick-walled resting spores called extramatricular chlamydospores, which can survive adverse soil conditions and germinate when conditions are favourable. The hyphae penetrate the root and ramify in the cortex producing highly branched hyphal structures called arbuscules and round to oval structures called vesicles. The presence of vesicles and arbuscules is the criteria for identifying AMF in the roots (Dar 2010). These fungi are obligate symbionts and have not been cultured so far on nutrient media. It is now proved beyond doubt that AMF greatly enhances plant growth.

The improved growth is mainly attributed to uptake of diffusion-limited nutrients, such as P, Zn, Cu, etc., from soil. The other beneficial effects are their role in the biological control of root pathogens, hormone production, greater ability to withstand abiotic stress, and synergistic interaction with nitrogen fixers, P solubilizers, and plant growth-promoting rhizo-bacteria (PGPR) (Bagyaraj 2011). The role played by these fungi in improving plant growth is much more significant in tropical soils compared to temperate soils. This is mainly because most of the soils of the tropics are of low inherent fertility and are deficient in phosphorus. In addition to being deficient in phosphorus, this nutrient also gets fixed in the soil and is not readily available over the crop period necessitating fresh additions. In acidic soils, they are fixed as iron and aluminium phosphates while in neutral soils they are fixed as calcium phosphates. Continuous application of P fertilizers will result in increased concentration of total phosphorus in the soil over time, thus resulting in large reserves of fixed P. According to Ozanne (1980), less than 10% of soil P enters the plant–animal cycle. Experiments with ^{32}P-labelled phosphorus conclusively proved that AMF cannot solubilize unavailable inorganic

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phosphorus sources but draw extra phosphate only from the labile pool in soil solution (Raj *et al.* 1981). The improved P nutrition in plants has been explained mainly by the extension of AMF hyphae beyond the root system which allows for the exploration of spatially unavailable nutrients (Smith *et al.* 2000). In exchange, the AMF receives carbohydrates from its host plant (Smith and Read 1997; Bagyaraj and Ashwin 2017).

Plant Growth Response to AMF Inoculation

Earlier experiments conducted in sterilized soil showed that AMF inoculation improved plant growth. Since most of the natural soils usually harbour AMF, it was felt that plants may not respond to mycorrhizal inoculation in unsterile soils. But later investigations indicated that even in unsterile soils, plants do respond to inoculation with efficient strains of AMF. Now it is proved beyond doubt that AMF improves plant growth. The growth increase is favoured in soils with low to moderate fertility, especially phosphorus being in limiting concentrations (Dodd and Jeffries 1986).

Selection of Efficient AMF for Inoculation

It is well known that AMF are not host specific. Though a particular AMF can infect and colonize many host plants, it has a preferred host, which exhibits maximum symbiotic response when colonized by that particular AMF (Abbott and Robson 1982). This led to the concept of 'host preference' in AMF and in turn, the procedure for screening and selecting an efficient fungus for a particular host. This, in turn, led to the selection of inoculant AMF for many crops important in agriculture, horticulture, and forestry (Gianinazzi *et al.* 1990; Bagyaraj and Kehri 2012). AMF are obligate symbionts. Attempts to culture AMF on artificial media have met with little or no success. At present, the most common method to mass produce these fungi is in association with the host plant root. Novel techniques to produce AMF inoculum in an almost sterile environment through nutrient film technique, circulatory hydroponic culture system, and root organ culture are also available (Bagyaraj 2016). However, in order to use AMF as a bio-fertilizer, there must be a technology that produces tonnes of AMF inoculum.

Use of AMF for Plant Growth

AMF inoculum of suitably selected strains can be used for inoculation in the nursery bed (Palazzo *et al.* 1994). Growers only need to incorporate inoculum in the nursery beds or seedling trays at the appropriate rate by hand. Seedlings thus raised will be colonized by the introduced fungus and can then be planted out in the field. There are several reports of increased growth and yield of food, fodder, and fuel crops due to inoculation with efficient AMF (Bagyaraj 2014b). These studies also brought out that because of inoculation, nearly 50% of phosphate fertilizer application could also be reduced (Thilagar *et al.* 2016; Anuroopa *et al.* 2017; Jyothi *et al.* 2018). Some horticultural plants are propagated through cuttings. In such cases, rooting of cuttings is important. Enhanced rooting of cuttings through inoculation with AMF has been reported. AMF-inoculated plants withstanding transplant stock have also been reported in avocado (Menge *et al.* 1980). Later studies showed high percentage of grafting success in cashew (Lakshmipathy *et al.* 2000). Inoculation of micropropagated plantlets with AMF after hardening also improved plantlet vigour and growth in coffee, grapevine, apple, avocado, pineapple, kiwi fruit, strawberry, raspberry, asparagus, and banana (Yao *et al.* 2002; Bagyaraj 2014b). The information available as to whether perennial plants already established in the field respond to AMF inoculation is very meagre. In a study, it was found that ten-year-old mulberry plants and one-and-half-year-old papaya trees positively responded to mycorrhizal inoculation (Mamatha *et al.* 2002). Thus, use of AMF can be considered as an alternate strategy to more rational and sustainable agriculture. Some success has been achieved with reference to some cash crops, horticultural plants, and medicinal plants.

Interaction between AMF and Other Beneficial Soil Microorganisms

There are several reports on the interaction between AMF and other beneficial soil microorganisms, such as N fixers, P solubilizers, PGPR, biocontrol organisms, and others. These studies brought out that the interaction is synergistic with consequential benefit to plant growth (Bagyaraj 2011). Recent studies have shown that inoculation with microbial consortium consisting of an efficient AMF together with N fixer, P solubilizer, and PGPR carefully screened and selected for a particular crop plant or forest tree species is more beneficial than AMF alone in improving the growth, biomass, and yield. In a recent study, chilly seedlings inoculated in the nursery with microbial consortium consisting of a selected AMF (*Funneliformis mosseae*) and a PGPR (*Bacillus sonorensis*) were planted in a farmer's field. Inoculated plants with 50% of NPK fertilizer performed equal to uninoculated plants receiving 100% NPK fertilizer (Thilagar *et al.* 2016). In another study, forest tree seedlings inoculated in the nursery with microbial consortium consisting of AMF + PGPR were planted in degraded forest. Inoculated plants survived and

grew significantly better compared to uninoculated plants 52 months after planting (Bagyaraj 2015).

Conclusion

The inoculation of seedlings with AM fungi is considered a safe and eco-friendly biotechnology, since these fungi occur naturally in the soils of most land ecosystems. Moreover, it is a low-cost technology which makes its application very viable. Further, it is essential to develop microbial consortia consisting of suitable AM fungi + PGPR to inoculate a plant important in agriculture, horticulture, and forestry in the nursery. This simple nursery technology will not only help to produce healthy, vigorously growing seedlings in the nursery but will also reduce transplant shock and ensure better survival, growth, and productivity when planted outside in the field. Finally, there is still a gap in the research and development framework and technology transfer in this area. It is likely that inoculation with microbial consortia consisting of effective AM fungi + PGPR will become an integral part of the nursery technology in the future. This simple technology will not only improve plant growth and productivity but will also reduce the usage of fertilizers and pesticides, thus minimizing environmental pollution.

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Morphotaxonomy of *Acaulospora Marrowie* (Accession CMCC/AM-2302)

*Varsha and Alok Adholeya**

Arbuscular mycorrhiza fungi (AMF) is an ecosystem service provider. The mycorrhizal colonization of the root cortex produced in the soil by AMF acts as access routes for plants to uptake low-mobility nutrients, including phosphorus (P), resulting in increased nutrient absorption and often plant growth (Smith and Read 2008).

Carrying forward our series of morphotaxonomic studies of successfully isolated and established AMF species, in this edition we will see the well-known genus that has been successfully maintained in the Centre for Mycorrhizal Culture Collection (CMCC) of TERI with the accession number CMCC/AM-2302.

Monosporal Establishment

The isolate of accession CMCC/AM-2302 was isolated from the trap raised from the soil of Chambal, Madhya Pradesh (India), with wild grass as host.

Healthy and mature AMF spores were recovered from trap cultures established with pot condition and Sorghum bicolor used as host plant were extracted by wet sieving (Gerdemann and Nicolson 1963) and used to establish single cultures. Monosporal culture was raised on the basis of morphological properties, that is, their size, structure, and colour to obtain pure single species culture of AMF. These cultures were later propagated under greenhouse conditions with same hosts for 90 days. Morphological properties of potential spores and their wall structure were determined by preparing voucher specimen of spores mounted Polyvinyl lacto glycerol (PVLG) and a mixture of PVLG and Melzer's reagent (1:1, v/v). Also, after the adequate growth period of about three to six months, host roots were examined for root colonization, colonization marks for successful cultures (Figure 1).

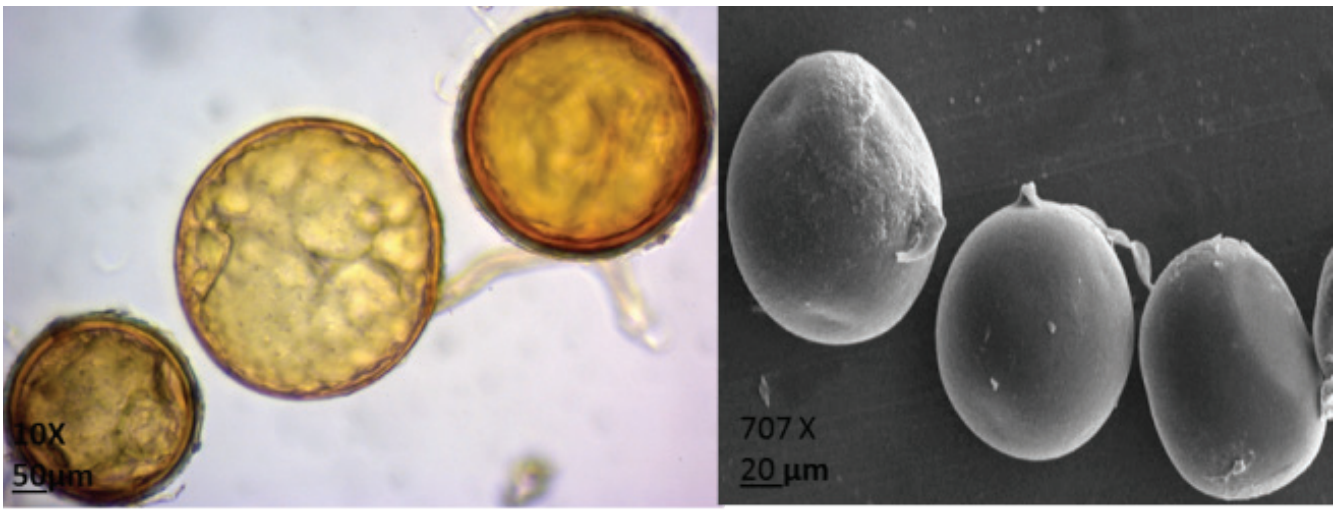

Figure 1: Compound microscopic images (10 X) and SEM (Scanning electron micrographs) of CMCC/AM-2302 showing spores

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Spore Morphology and Shape

Spores isolated from monosporal cultures are borne in soil singly. The colour of spores ranged from sub hyaline while young to pale yellow brown at maturity. Scanning Electronic Micrograph (SEM) of the spores revealed an outer smooth wall surface in mature spores with no prominent pits (Figure 2). The shape of spores varied from globose to subglobose, (70–) 100(–120) µm diam. (Figure 3).

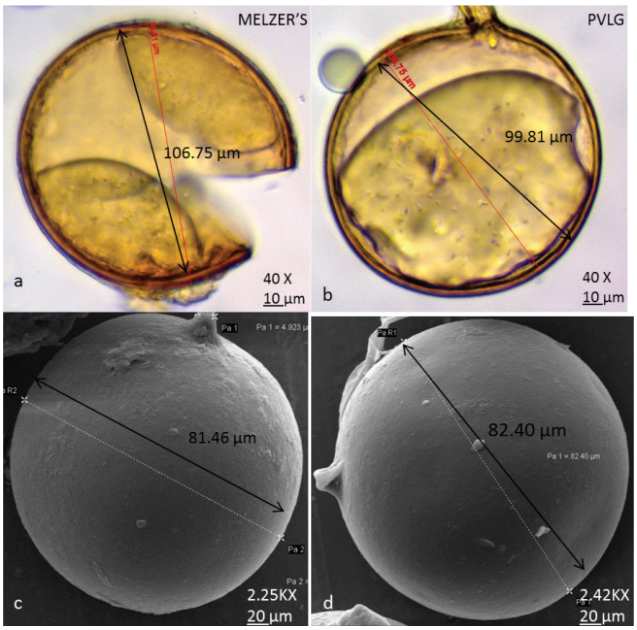

Figure 2: Compound microscopic images (40X) and SEM (2.42KX) of mature spores of accession CMCC/AM-2302 showing globose to subglobose shaped spores. SEM images reveal smooth outer layer of the spore

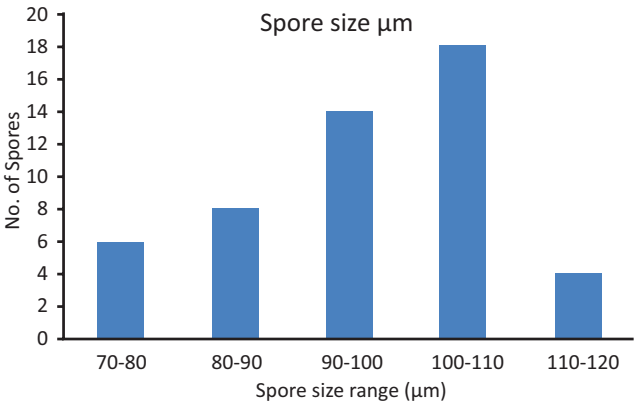

Figure 3: Analysis of spore diameter of 50 healthy and cleaned spores obtained from one-year old monosporal culture of accession CMCC/AM-2302

Subcellular Structure of the Spore

Mature spore showed very less reaction with polyvinyl lacto glycerol: Melzer's reagent but no reaction was seen with polyvinyl lacto glycerol (PVLG). There are three layers (L1, L2, and L3) of the spore (Figure 4).

Spore Wall Layer 1 (L1)

This layer forms the spore surface. The outer layer is continuous with the wall of the neck of the parent sporiferous saccule. Layer 1 deteriorates with age and is hyaline and smooth. Thickness of this layer is 0.7–1.2 µm.

Spore Wall Layer 2 (L2)

Layer 2 is laminate and smooth. This layer is of pale yellow to yellow in colour. Thickness of this layer is 2.4–3.8 µm.

Spore Wall Layer 3 (L3)

Layer 3 is 0.8–1.1 µm thick and is often adherent to the spore wall. With slight separation in some broken spores, it can be seen, but it rarely separates completely from the spore wall.

GERMINAL WALLS

These spores have two adherent hyaline inner walls (GW1 and GW2), with GW 1 sometimes not very clearly observed if it does not separate cleanly from the spore wall, whereas GW2 separates from spore wall and is easily identified (Figure 4).

GW1: is a flexible, hyaline wall. Thickness of this layer ranges from 0.5–0.8 µm.

GW2: L2 is hyaline and plastic. It stains red-purple with PVLG: Melzer's reagent.

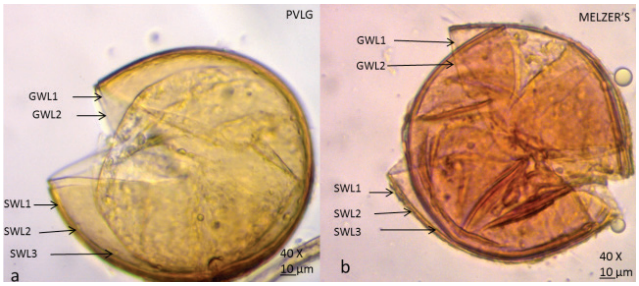

Figure 4: Compound microscopic images of spore wall layers and germinal wall layers of CMCC/AM-2302 after mounting in PVLG reagent (A) and PVLG:MELZER's reagent (B)

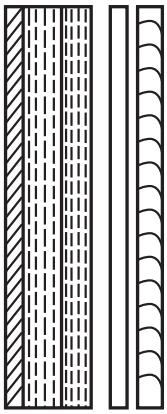

Figure 5: Murograph (Walker 1983) of the mature spore showing three distinct wall layers of CMCC/AM-2302

Sporiferous Saccule

There is a hyaline saccule which is mostly gobose to subglobuse and occasionally irregular. Saccule mostly collapses in mature spores. It has single smooth wall layer.

Cicatrix

Saccule neck and spore are in contact with a circular, sometimes oval-shaped scar like region which is known as cicatrix.

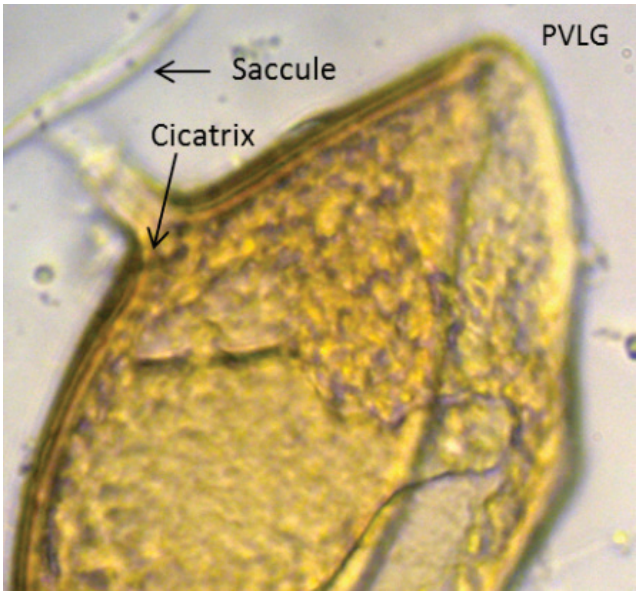

Figure 6: Compound microscopic image of sporiferous saccule and cicatrix (Morton 1986) of CMCC/AM-2302 after mounting in PVLG reagent

Mycorrhiza

From the monosporal culture of accession CMCC/AM-2302, the host roots are harvested and stained in ink vinegar. Mycorrhiza structures, such as arbuscules, extra and intraradical hypha, are observed. Root colonization assays showed the presence of both extraradical and intraradical hyphae. Arbuscules are abundant and are dispersed evenly through the root cortex. Intra-radical vesicles are also present (Figure 7).

Conclusion and Classification Level

On the basis of above morphotaxonomic analysis of the accession CMCC/AM-2302, many distinguishing features regarding the family, genera, and the species could be derived. The following features were taken into consideration for characterization and identification:

Globose, asexual spores produced singly with three-layered spore walls.

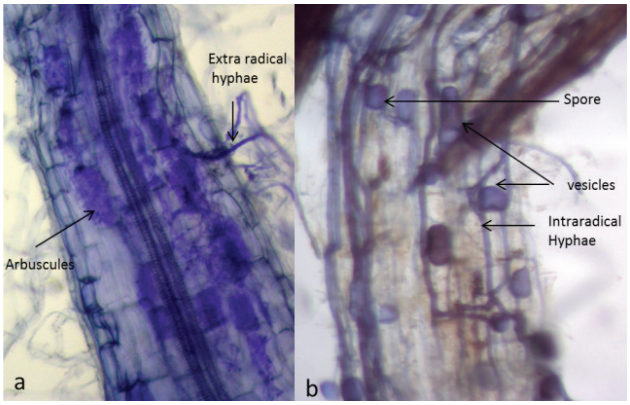

Figure 7: Compound microscopic images of roots of *Sorghum bicolor* stained in ink vinegar and observed for root colonization by CMCC-AM-2302 showing intraradical and extraradical hypha (a and b) and abundant arbuscules (a) vesicles in the cortical cells (b). Spores are also seen (b)

Spore wall layer is composed of outer mucilaginous layer followed by two smooth inner laminated layers, that is, continuous with the germinal wall.

There are two layers of germinal wall. Outer layer is hyaline and sometimes remains unrecognized in mature spore whereas second layer always separates and can be easily identified.

Spores are of varying shapes and sizes ranging from globose to subglobose.

Formation of both intraradical and extraradical hyphae and abundant vesicles and intra-cellular arbuscules.

All these features suggest that the culture CMCC/AM-2302 belongs to the family *Acaulospora Morrowiae* (Schenck 1984).

Some of the unique morphotaxonomic features of the accession are detailed as follows:

Subhyaline to pale yellow, globose, asexual spores produced singly with layered spore walls; spores are of varying shapes and sizes ranging from globose to subglobose. Size ranges 70 – (100) – 120 µm.

Spore wall layer is composed of outer hyaline layer, inner smooth laminate layer and innermost adherent layer that is continuous with the subtending germinal wall.

Outer germinal wall layer is hyaline and sometimes unrecognized and second easily identifiable layer.

Formation of both intraradical and extraradical hyphae and abundant vesicles and intracellular arbuscules.

The taxonomic feature of the accession CMCC/AM-2702 matches the characters of *Acaulospora Morrowiae* (Schenck 1984).

Systematic Classification

Glomeromycota
Glomeromycetes
Diversispoiales
Acaulosporaceae
Acaulospora
Acaulospora Morrowiae

Conventional methods for identifying a species are usually based on taxonomic identification of organisms, assembling key characters, and comparing these with existing reference or type species. In practice this approach is useful for taxa that are well known and when individuals can be readily identified, but it can be a serious problem when species cannot be identified based on existing references. Therefore, traditional taxonomic approaches to characterize an individual may not have significant advantages over alternative methods. Identities of individual organisms that are closely related to each other are made easier and accurate by sequencing the conserved sequences. Analyses of rDNA regions have often confirmed the morphologically defined species, and the molecular data have characterized new genera and families in AM taxonomy. It is therefore advised to our distinguished readers to kindly correlate their morphotaxonomic studies with molecular phylogenetic results.

Acknowledgements

We acknowledge the contribution of Awadhesh Ram for maintenance of AMF cultures. Technical assistance provided by Chandrakant Tripathi during scanning electron microscopy of AMF spores is also thankfully acknowledged.

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Mycorrhiza helper bacteria enhance the ectomycorrhizal growth in plants

C Manoharachary[a] and Anurag Nath[b]*

Mycorrhiza helper bacteria (MHB) are microorganisms which belong to the protobacteria, actinobacteria, and firmicutes phyla, form symbiotic associations with ectomycorrhiza and also arbuscular mycorrhizal fungi. The commonest bacteria belong to *Pseudomonas*, *Streptomyces*, and others. The primary function of MHB is to enhance the functional role of mycorrhiza along with increasing the growth of mycorrhizal biomass and enhancing its nutritional abilities. They not only assist the host plants but also the ectomycorrhiza present in the symbiotic association. Their other functions include promotion of defence against pathogens to the host and fungus and also improvement of soil conductance. The common MHBs include *Pseudomonas fluroscens*, *Streptomyces sp.*, *Bacillus sp.*, and others. MHB helps in detoxifying soil by preventing the accumulation of heavy metals and also helps in the control of pathogens by releasing anti-fungal metabolites. Genera, such as *Pisolithus*, *Russusa*, *Coenococcus*, *Tricholoma*, *Amanita*, *Laccaria*, *Rhizopogon*, *Skillus*, and others have been found associated with helper bacteria.

The influence of mycorrhiza in the enhancement of plant growth has been known for decades. Almost 90% of all the terrestrial plants have been observed to have small mycorrhizal colonization in the roots. These colonies offer multiple advantages to the host plants. They assist in improving the quality and yield of plant products by providing an increased surface area for the establishment of hyphae which eventually instead increase the nutrient uptake. Mycorrhizal community in their natural environment are surrounded by other microbial species which exist in mutual symbiosis with each other. The microbial community has been found to modulate the association of mycorrhiza with plants. These MHB can be categorized as those which improve the mycorrhiza formation and those which enhance the mycorrhizal association by promoting symbiosis. Evidences suggest that MHB assists in building and maintaining the ecological balance (reference). These MHBs are specific to species of mycorrhiza and their ability and mechanism to associate with mycorrhiza differs depending on the mycorrhizal species and the surrounding microbial community (reference). However the specificity of MHB is not bound to the host plant species (reference 2). The microbial community promotes atmospheric nitrogen fixation, nutrient mobilization from soil and also improves the defence mechanism of plants against pathogens (mechanism).

The establishment of a mycorrhizal micro-environment in the soil involves significant modifications in the soil and the fungus. The bacterial community present in the soil has been reported to assist in the morphological and physiological changes of the root and soil necessary for the plants to sustain (reference x). The bacterial community develops selective interaction with microbial community surrounding the plants specifically showing a neutral or positive impact towards the mycorrhiza association and subsequently promoting the same. In contrast, it shows a negative impact on the root pathogens present in the soil. Primarily, MHB have been assumed to be involved in five functions when concerned with mycorrhiza association—root receptivity with the mycobiont, the recognition between root and fungus, improving the fungal growth, modifying the soil environment, and germination of the fungal fruiting bodies. *Pseudomonas* has been found to be well associated with ectomycorrhiza and improves the host plant defence mechanism against pathogens (reference 2).

The interface among soil and the root of fungus is a dynamic microenvironment where the soil constituents interact to produce a rhizosphere. Thus, rhizosphere happens to be the zone where there is an increased microbial activity and association among the microbiota and the soil components. This environment is distinct from the bulk soil. The bulk soil microorganisms are different from those present in the rhizosphere. The microorganisms (both symbiotic and free living) found in this environment assist the host plants to adapt to the abiotic stress conditions, such as drought, nutrient deficiency, and plant pathogens. The mutualism among the plant and mycorrhizal fungi is highly influenced by the microorganisms in the rhizosphere, especially bacteria. Though majority of such interactions are competitive and result in negative implications, yet some of the plant infections are beneficial and assist in improving the host defence mechanism against pathogens. MHBs stimulate the established symbiotic association and cause positive interaction among them. The positive regulation of rhizosphere bacteria can be categorized as Mycorrhization Helper Bacteria (those bacteria which facilitate mycorrhization) and Mycorrhiza Helper Bacteria (those which enhance

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the positive interaction among the host plant and fungal community). Although the categorization is different yet the organisms belonging to the category tend to be overlapping. These organisms serve for the boosting of the mycorrhizal population and enhancement of the symbiotic association. It has been proposed that this phenomenon can be utilized for improving the agricultural productivity by providing an inoculum containing the specific microbial species which can facilitate the interaction among the host plant and the bacteria (http://dx.doi.org/10.1590/S1517-83822010000400002). Mycorrhiza has been a promising field of research and considering the current stressful environment the plants undergo, it can act as a boon for increasing the commercial value of crops.

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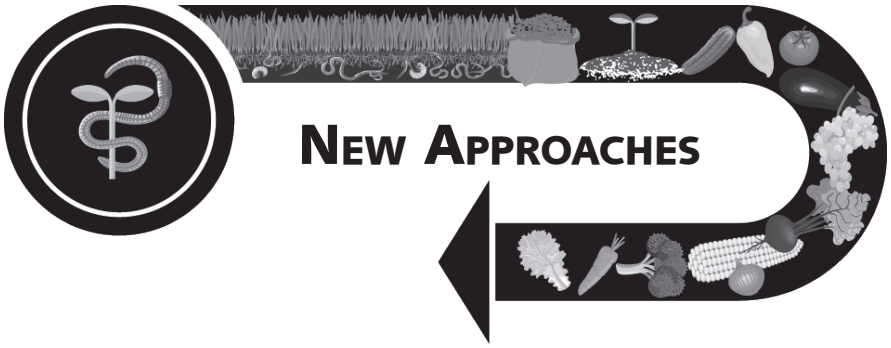

New Approaches and Techniques

1. Advanced Multiplication of mycorrhiza using molecular characterization Chellappan P, Mohan N, Ramesh C, Selvaraj T, Arunachalam M, Mahadevan A. (2005). A new approach for enhanced multiplication of arbuscular mycorrhizal fungi and isolation of ITS regions from *Glomus deserticola* and *Laccaria fraternal*.

   The multiplication of arbuscular mycorrhiza is a requirement for understanding their underlying mechanism. However, an efficient technique for increasing the colonization of mycorrhiza fungi shall involve the molecular biomarkers as a tool for identifying the specific fungal DNA locations. These DNA segments contribute towards the multiplication and progress of fungal spores and hyphae. Modification of such segments might enable the mycorrhiza species to undergo frequent fungal multiplication and subsequent colonization. The increased colonization will increase the area of interaction among the host plant and fungi thereby improving the mutual symbiotic association among the host plant and the fungi facilitating a better interaction among them. The extracted DNA sequences can be used for further molecular classification and estimation of the fungal species.

2. Identification of mycorrhiza using ESTs Franken, P and Requena, N. (2001). Analysis of gene expression in arbuscular mycorrhizas: new approaches and challenges. *New Phytologist*, 150(3): 517–523.

   Expressed Sequence Tags (ESTs) can be used for the identification of arbuscular mycorrhiza. Libraries of cDNA can assist in identifying mycorrhizal junctions wherein the sequence tags assisting in symbiosis can be used for establishing a better network of mycorrhiza. The molecular analysis of mycorrhizal population using ESTs shall act as an efficient technique for the better classification of the mycorrhiza based on their significant marker expression and associated with their lifestyle and microenvironment. The mechanisms involved in the symbiotic association can be well understood and incorporated for the enhancement of plant production.

ANNOUNCEMENTS

In 2016–17, TERI set up the world's biggest facility for mycorrhiza production in Gual Pahari in Gurugram, Haryana.

Submission to *Mycorrhiza News* in the form of relevant notes; brief write-ups highlighting current research achievements; news/events of common interest to members like seminars/workshops attended, in the field of mycorrhiza are always welcome! Members are requested to provide the MIC (Mycorrhiza Information Center) with copies of articles,papers,reports,reviews,etc., dealing with mycorrhiza for the proper dissemination of mycorrhizal information amongst researchers.

The Mycorrhiza website www.mycorrhizae.org.in is currently undergoing transformation and will soon be revamped into a better and much more informed website with new added features for better information dissemination.

Recent references

The latest additions to the network's database on mycorrhiza are published here for the members' information. The list consists of papers from the following journals:

- *Agricultural Water Management*
- *Applied Soil Ecology*
- *Biochemical Systematics and Ecology*
- *Ecological Engineering*
- *Ecotoxicology and Environmental Safety*
- *Environmental Technology & Innovation*
- *European Journal of Soil Biology*
- *Forest Ecology and Management*
- *Fungal Ecology*
- *Geoderma*
- *Journal of Environmental Sciences*
- *Journal of Plant Physiology*
- *Rhizosphere*
- *Scientia Horticulturae*
- *Soil Biology and Biochemistry*
- *South African Journal of Botany*

Copies of papers published by mycorrhizologists during this quarter may please be sent to:
Mr Anurag Nath (anurag.nath@teri.res.in) for inclusion in the next issue.

Name of the author(s) and year of publication	**Title of the article, name of the journal, volume number, issue number, page numbers (address of the first author or of the corresponding author, marked with an asterisk)**
Bahnmann B, Mašínová T, Halvorsen R, Davey ML, Sedlák P, Tomšovský M, Baldrian P. 2018	**Effects of oak, beech and spruce on the distribution and community structure of fungi in litter and soils across a temperate forest** *Soil Biology and Biochemistry* **119**: 162–173 [*Laboratory of Environmental Microbiology, Institute of Microbiology of the CAS, Vídeňská 1083, 14220 Praha 4, Czech Republic]
Chen X, Ding Z, Tang M, Zhu B. 2018	**Greater variations of rhizosphere effects within mycorrhizal group than between mycorrhizal group in a temperate forest** *Soil Biology and Biochemistry* **126**: 237–246 [*Institute of Ecology, College of Urban and Environmental Sciences, and Key Laboratory for Earth Surface Processes of the Ministry of Education, Peking University, Beijing, 100871, China]
Decruse SW, Neethu RS, Pradeep NS. 2018	**Seed germination and seedling growth promoted by a Ceratobasidiaceae clone in Vanda thwaitesii Hook. f., an endangered orchid species endemic to South Western Ghats, India and Sri Lanka** *South African Journal of Botany* **116**: 222–229 [*Biotechnology and Bioinformatics Division, Jawaharlal Nehru Tropical Botanic Garden and Research Institute, Palode, Thiruvananthapuram 695 562, India]
Demenois J*, Carriconde F, Bonaventure P, Maeght J-L, Stokes A, Rey F. 2018	**Impact of plant root functional traits and associated mycorrhizas on the aggregate stability of a tropical Ferralsol** *Geoderma* **312**: 6–16 [*Institut Agronomique néo-Calédonien (IAC), Equipe Sol & Végétation (SolVeg), BP18239, 98848 Nouméa, New Caledonia]
Detheridge AP*, Comont D, Callaghan TM, Bussell J, Brand G, Gwynn-Jones D, Scullion J, Griffith GW. 2018	**Vegetation and edaphic factors influence rapid establishment of distinct fungal communities on former coal-spoil sites** *Fungal Ecology* **33**: 92–103 [*Institute of Biological, Environmental and Rural Sciences, Aberystwyth University, Adeilad Cledwyn, Penglais, Aberystwyth, Ceredigion SY23 3DD Wales, United Kingdom]
Frew A*, Powell JR, Glauser G, Bennett AE, Johnson SN. 2018	**Mycorrhizal fungi enhance nutrient uptake but disarm defences in plant roots, promoting plant-parasitic nematode populations** *Soil Biology and Biochemistry* 126: 123–132 [*Hawkesbury Institute for the Environment, Western Sydney University, Richmond, NSW, Australia]

Name of the author(s) and year of publication	Title of the article, name of the journal, volume number, issue number, page numbers (address of the first author or of the corresponding author, marked with an asterisk)
Gai JP, Fan JQ, Zhang SB, Mi NN, Christie P, Li XL, Feng G. 2018	**Direct effects of soil cadmium on the growth and activity of arbuscular mycorrhizal fungi** *Rhizosphere* **7**: 43–48 [*College of Natural Resources and Environmental Sciences, China Agricultural University, Beijing 100193, China]
Hassiotis CH. 2018	**The role of aromatic** *Salvia officinalis L.* **on the development of two mycorrhizal fungi** *Biochemical Systematics and Ecology* **77**: 61–67 [Etherio Research Laboratory, Essential Oils, Eratera, 50003, Voio, Greece]
Hassiotis CN*, Orfanoudakis M. 2018	**The impact of** *Lavandula stoechas L.* **degradation on arbuscular mycorrhizal fungi, in a Mediterranean ecosystem** *Applied Soil Ecology* **126**: 182–188 [*Etherio Research Laboratory, Essential Oils, Eratera 50003, Askio, Greece]
Iason GR, Taylor J, Helfer S. 2018	**Community-based biotic effects as determinants of tree resistance to pests and pathogens** *Forest Ecology and Management* **417**: 301–312 [*The James Hutton Institute, Craigiebuckler, Aberdeen AB15 8QH, United Kingdom]
Janoušková M, Kohout P, Moradi J, Doubková P, Rydlová J, 2018	**Microarthropods influence the composition of rhizospheric fungal communities by stimulating specific taxa** *Soil Biology and Biochemistry* **122**: 120–130 [*Department of Mycorrhizal Symbioses, Institute of Botany of the Czech Academy of Sciences, Zámek 1, 25243, Průhonice, Czech Republic]
Li J*, Sun Y, Jiang X, Chen B, Zhang X. 2018	**Arbuscular mycorrhizal fungi alleviate arsenic toxicity to Medicago sativa by influencing arsenic speciation and partitioning** *Ecotoxicology and Environmental Safety* **157**: 235–243 [*tate Key Laboratory of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, No. 18, Shuangqing Road, Haidian District, Beijing 100085, China]
Liu C-Y, Wang P, Zhang D-J, Ying-Ning Z, Kuůa K, Qiang-Sheng W. 2018	**Mycorrhiza-induced change in root hair growth is associated with IAA accumulation and expression of EXPs in trifoliate orange under two P levels** *Scientia Horticulturae* **234**: 227–235 [*College of Horticulture and Gardening, Yangtze University, Jingzhou, Hubei 434025, China]
Mahanta D, Rai RK, Dhar S, Varghese E, Raja A, Purakayastha TJ. 2018	**Modification of root properties with phosphate solubilizing bacteria and arbuscular mycorrhiza to reduce rock phosphate application in soybean-wheat cropping system** *Ecological Engineering* **111**: 31–43 [*ICAR-Indian Agricultural Research Institute, New Delhi, 110 012, India]
Maldonado-Mendozaa IE, Harrison MJ. 2018	**RiArsB and RiMT-11: Two novel genes induced by arsenate in arbuscular mycorrhiza** *Fungal Biology* **122**(2–3): 121–130 [nstituto Politécnico Nacional, Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional (CIIDIR)-IPN Unidad Sinaloa, Departamento de Biotecnología Agrícola, Blvd. Juan de Dios Bátiz Paredes No. 250, AP280, Guasave, Sinaloa CP81101, Mexico]
Mohammad B, Reza N, Davoud K. 2018	**Milkweed seedlings tolerance against water stress: Comparison of inoculations with** *Rhizophagus irregularis* **and** *Pseudomonas putida* *Environmental Technology & Innovation* **10**: 111–121 [*Young Researcher and Elites Club, Science and Research Branch, Islamic Azad University, Tehran, Iran]

Name of the author(s) and year of publication	Title of the article, name of the journal, volume number, issue number, page numbers (address of the first author or of the corresponding author, marked with an asterisk)
Papp M, Fóti S, Nagy Z, Pintér K, Posta K, Fekete S, Csintalan Z, Balogh J. 2018	**Rhizospheric, mycorrhizal and heterotrophic respiration in dry grasslands** *European Journal of Soil Biology* **85**: 43–52 [MTA-SZIE Plant Ecology Research Group, Szent István University, 2100 Gödöllő, Páter K. u. 1, Hungary]
Pereira LS*, de Araújo RP, de Oliveira PS, da Silva LD, Alves PAC, Fernandes VF, Gross E. 2018	**Cadmium induced changes in** *Solidago chilensis* **Meyen (Asteraceae) grown on organically fertilized soil with reference to mycorrhizae, metabolism, anatomy and ultrastructure** *Ecotoxicology and Environmental Safety* **150**: 76–85 [*Programa de Pós-Graduação em Biologia e Biotecnologia de Microorganismos, Universidade Estadual de Santa Cruz, Ilheus, Bahia, Brazil]
Pirzad A*, Mohammadzadeh S. 2018	**Water use efficiency of three mycorrhizal Lamiaceae species (***Lavandula officinalis***,** *Rosmarinus officinalis* **and** *Thymus vulgaris***)** *Agricultural Water Management* **20**4: 1–10 [*Department of Agronomy, Faculty of Agriculture, Urmia University, Urmia, Iran]
Sujkowska-Rybkowska M, Czarnocka W, Sańko-Sawczenko I, Witoń D. 2018	**Effect of short-term aluminum stress and mycorrhizal inoculation on nitric oxide metabolism in** *Medicago truncatula* **roots** *Journal of Plant Physiology* **220**: 145–154 [Department of Botany, Faculty of Agriculture and Biology, Warsaw University of Life Sciences (SGGW), Nowoursynowska Street 159, 02-776 Warsaw, Poland]
Sujkowska-Rybkowska M, Znojek E. 2018	**Localization of calreticulin and calcium ions in mycorrhizal roots of Medicago truncatula in response to aluminum stress** *Journal of Plant Physiology* **229**: 22–31 [*Department of Botany, Faculty of Agriculture and Biology, Warsaw University of Life Sciences-SGGW, Nowoursynowska 159, 02-776, Warsaw, Poland]
Xu L, Li T, Wu Z, Feng H, Yu M, Zhang X, Chen B. 2018	**Arbuscular mycorrhiza enhances drought tolerance of tomato plants by regulating the 14-3-3 genes in the ABA signaling pathway** *Applied Soil Ecology* **125**: 213–221 [State Key Laboratory of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China]
Zhang X, Ren B, Wu S, Sun Y Chen B, Li R. 2018	**Rhizophagus irregularis influences As and P uptake by alfafa and the neighboring non-host pepperweed growing in an As-contaminated soil** *Journal of Environmental Sciences* **67:** 36–44 [*State Key Laboratory of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China]

Forthcoming events conferences, congresses, seminars, symposiums, and workshops

Osaka, **Japan** January 28–29, 2019	**13th International Conference on Agriculture and Plant Science** **Theme: Current Trends in Agriculture and Plant Science** *Email:* agrisummit@worldmeet.net *Website:* https://agriculture.conferenceseries.com/
London, **United Kingdom** February 25–26, 2019	**2nd World Conference on Soil Microbiology, Ecology and Biochemistry** **Theme: The Future of Ecosystem, Ecosystem for Future** *Email:* ecology@expertsconferences.org *Website:* https://ecology.environmentalconferences.org/
Osaka, **Japan** February 28–March 1, 2019	**7th Annual Congress on Plant Science and Molecular Biology** **Theme: Advancements & Innovations in Plant Science, Crops & Ecosystem** *Email:* plantscience@asia.com *Website:* https://world.plantscienceconferences.com/
Chicago, Illinois, **USA** March 18–19, 2019	**3rd International Conference on Ecology, Ecosystem and Conservation Biology** **Theme: Exploring the Possibilities for a Better Environment** *Email:* ecologyecosystems@annualamericacongress.org *Website:* https://ecologyecosystems.conferenceseries.com/
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The Mycorrhiza News provides a forum for dissemination of scientific information on mycorrhiza research and activities; publishes state-of-the-art papers from eminent scientists; notes on important breakthroughs; brief accounts of new approaches and techniques; publishes papers complied from its RIZA database; provides information on forthcoming events on mycorrhiza and related subjects; lists important research references published during the quarter; and highlights the activities of the CMCC.

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