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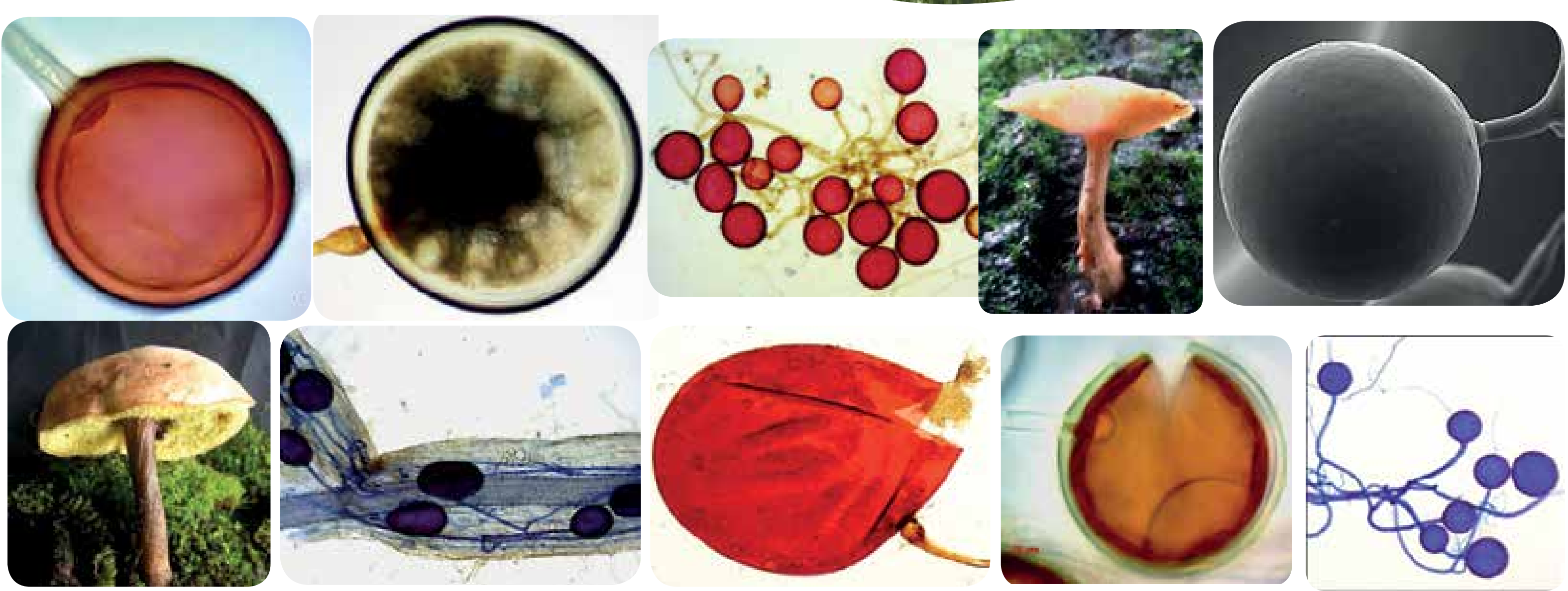

About **TERI**

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.

CONTENTS

Research finding papers

Mycorrhizal Status of Some Plants of the Euphorbiaceae Family in Solapur, Maharashtra

Sandhya S Gaikwad,[a] N S Mali,[b] and Prakash P Sarwade[c]*

Introduction

Mycorrhiza is a mutualistic association between fungi and higher plants (Menge 1983). Frank (1885) coined the term mycorrhizae. The term 'mycorrhiza' in its broadest sense is the non-pathogenic association of fungi and the roots of higher plants. The root–fungus association is symbiotic, and the whole association is considered as a 'functionally distinct organ' involved in mineral nutrient uptake from the soil (Kar 1993).

Euphorbiaceae is large and extremely variable family, which includes 300 genera and 5000 species, cosmopolitan in distribution except in the Arctic region, but they are most abundant in the tropical regions. In India, the family is represented by about 61 genera and 336 species mostly in the tropical and subtropical Himalayas and the mountains of South India. Some members of this family (*viz. Acalypha indica, Chrozophora prostrate, C. rottleri, Croton bonplandianum, Euphorbia geniculata, E. caducifolia, E. dracunculoides, E. hirta, E. laciniata, E. prostrate, E. pulcherrima, Jatropha curcas, J. glandulifera, J. gossypifolia, Phyllanthus acidus*, and *P. amarus)* are multipurpose plant species commonly found in the state of Maharashtra. Hence, a study survey was conducted in Solapur district, where the plants are grown throughout the year to observe arbuscular mycorrhizal (AM) fungal genera that are associated with 60 plants.

Materials and Methods

Solapur district lies between 17°1'–18°32' north latitudes and 74°42'–76°15' east longitudes and is located entirely in the Seena basin. Barshi Taluka is one of the 11 tehsil headquarters of Solapur District in Maharashtra. This tehsil occupies the northeast corner of the district and is bordered by Osmanabad District to the north and east, Madha Taluka to the west, Mohol Taluka to the southwest, and North Solapur Taluka to the south.

Collection of different plants with their roots and soil were done randomly around Barshi tehsil in three replications. Root samples were washed in tap water and cut into one centimetre pieces in length. Root samples were cleared and stained using Phillips and Hayman (1970) technique. Root colonization was measured according to the Giovannetti and Mosse (1980) method. Hundred grams of rhizosphere soil samples were analysed for their spore isolation by wet sieving and decanting method (Gerdmann and Nicolson 1963). Identification of AM fungal genera up to species level was done using the *Manual for Identification* by Schenck and Perez (1990).

Results and Discussion

Plant species along with their AM fungi characterizations are presented in the Table 1. All the tested plants were colonized by AM fungi. The percentage of colonization was highest in *J. curcas* (94%) than other plants whereas, lowest percentage found in *C. rottleri* (35%). Hyphal and vesicular types of colonization were found in roots of different plants. Hyphae were almost common in all tested plants. Maximum number of spores (309) was observed in rhizosphere soil of *J. curcas*. Minimum number of spores (20) was observed in rhizosphere soil of *C. rottleri*. Four genera were observed, *viz. Acaulospora*

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spp *Glomus* spp, *Scutellospora* spp, and *Gigaspora* spp. Highest number of AM fungal genera and species were associated with *J. gossypifolia* while the lowest number was associated with *C. bonplandianum*. Among AM fungal species, *Acaulospora* spp were found dominating followed by *Glomus* spp; *Scutellospora* spp and *Gigaspora* spp were found poorly distributed.

Table 1 Percentage of root colonization and spore population in plants of Euphorbiaceae

Sr No.	Plant species	Colonization (%)*	Types of colonization	Spore population*	AM fungal genera
1	*Acalypha indica* L.	48	H	57	*Glomus* spp *Acaulospora* spp
2	*Chrozophora prostrata* Dalz.	64	H	80	*Glomus* spp *Acaulospora* spp *Gigaspora* spp
3	*Chrozophora rottleri* (Geis.) Juss. Ex Spreng.	35	H	20	*Glomus* spp *Acaulospora* spp
4	*Croton bonplandianum* Baill.	87	HV	281	*Acaulospora* spp
5	*Euphorbia geniculata* Orteg.	53	HV	134	*Glomus* spp *Acaulospora* spp *Gigaspora* spp
6	*Euphorbia caducifolia* Haines	87	HV	142	*Glomus* spp *Acaulospora* spp
7	*Euphorbia dracunculoides* Lamk.	56	HV	184	*Glomus* spp *Acaulospora* spp
8	*Euphorbia hirta* L.	85	H	138	*Glomus* spp *Acaulospora* spp
9	*Euphorbia laciniata* Panigrahi	34	H	84	*Glomus* spp *Acaulospora* spp
10	*Euphorbia prostrata* Ait.	65	HV	93	*Glomus* spp *Acaulospora* spp *Gigaspora* spp
11	*Euphorbia pulcherrima* Willd. ex Klotzsch	38	HV	234	*Glomus* spp *Acaulospora* spp
12	*Jatropha curcas* L.	94	HV	309	*Glomus* spp *Acaulospora* spp *Gigaspora* spp
13	*Jatropha glandulifera* Roxb.	89	HV	145	*Glomus* spp *Acaulospora* spp
14	*Jatropha gossypifolia* auct.	38	HV	163	*Glomus* spp *Acaulospora* spp *Gigaspora*spp *Scutellospora* spp
15	*Phyllanthus acidus* (L.) Skeels	54	HV	183	*Glomus* spp *Acaulospora* spp
16	*Phyllanthus amarus* Schumach. & Thonn.	57	H	138	*Glomus* spp *Acaulospora* spp

*Mean of three samples; H, Hyphae; V, Vesicular

AM association is the most frequently observed symbiosis found in nature because of their broad association with plants and cosmopolitan distribution (Harley and Smith 1983). Occurrence of AM fungi in Euphorbiaceae plants has been reported earlier by Mohan and Natarajan (1988), Raja *et al.* (1991), Raghupathy *et al.* (1988), and Parameswaran and Augustine (1988). Recently, Mulani and Prabhu (2002) and Gaikwad *et al.* (2013) reported the occurrence of AM fungi in Euphorbiaceae plants from India.

AM spore population also showed variation in the rhizosphere soils of selected plants (Table 1). Variations of spore number have been reported recently by Sarwade *et al.* (2011) and recorded difference in spore numbers between plant species.

Present study revealed the occurrence of four AM fungal genera, *viz.*, *Glomus, Acaulospora, Gigaspora*, and *Scutellospora*. *Acaulospora* were most dominant with plants growing in soils of Barshi Taluka. Recently, it has been confirmed by Sarwade *et al.* (2011). This contrasts with the report by Sarwade *et al.* (2012) that *Glomus* species is dominant.

The root colonization by AM fungi is a dynamic process. The results obtained from the present study suggest that all the test plants showed good colonization. However, percentage of root colonization varied from plant to plant (Table 1). Variations in extent of medicinal plant species were observed and confirm earlier findings of Muthukumar and Udaiyan (2000).

The study suggests that the colonization percentage and number of AM fungal spores differ between 60 plants. Highest number of mycorrhizal spores and root colonization of *J. curcas* indicated that these plant species might be considered good host for AM fungi under natural conditions. In conclusion, occurrence or distribution of AM fungi varies with host ranges. Studies on distribution and mycorrhizal status of plants should enable us to understand the influence of these mycobionts on plant species diversity and distribution.

Acknowledgements

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Centre for Mycorrhizal Culture Collection

Morpho Taxonomy of *Glomus drummondii/Claroideoglomus drummondii* (Accession CMCC/AM-2601)

*Kiran Sunar, Aditi Pandit, and Alok Adholeya**

Arbuscular mycorrhiza fungi (AMF) are a unique group of microorganisms that show distinct morphological characters across families and genera. The taxonomy of AMF belonging to Glomales is based principally on the structure of their spores or sporocarps; however, most of the characters are not genetically governed and are more or less influenced by the environment. The key characters such as spore wall, hyphal wall, nature of attachment, and branching and sporulation pattern remain the same (Morton 1990). So far, new technologies and advancement in microscopy and staining procedure have greatly facilitated observing specific characters and developing reliable taxonomic keys for species identification. Such characters were used to construct a dichotomous key (Hall and Fish 1979) and later a synoptic key (Trappe 1982). One of the most important characters that has been given weightage and is considered to be a key factor in determining genera and species in AMF taxonomy is the wall character, and this has been extensively used to develop artificial keys of almost all the Glomales (Walker 1983). Considering the importance of taxonomic characterization in nomenclature of AMF, we have been presenting detailed description of AMF isolates that are being maintained in our Centre for Mycorrhiza Culture Collection (CMCC) germplasm bank. In this article, we present the morphotaxonomic characterization of one of a unique AMF bearing accession number CMCC/AM-2601.

Monosporal Establishment

The isolate designated as CMCC/AM-2601 was isolated from the trap cultures that were raised with the soil samples from Germany. Trap cultures were raised for proliferation of indigenous mycorrhiza in pot conditions with a suitable host for a period of three months. After adequate growth cycle of the host plant, spores propagated in trap culture were checked by wet sieving and decanting method (Gerdeman and Nicholson 1963) and were categorized on the basis of their morphology. In the next step, all healthy spores were grouped according to their size, structure, and colour. Morphologically similar types of spores were grouped or isolated for obtaining pure single species culture of AMF. Voucher specimens of all the potential monosporal were prepared, and morphotaxonomic analysis of the spore and its wall layers, hyphal attachment, etc. were carried out under compound microscope (10×, 40×, and 100×) after mounting in Polyvinyl Lacto glycerol and Polyvinyl Lacto glycerol: Melzer's reagents (1:1). Selected healthy, single AMF spores were used to raise monospecific cultures that were inoculated to pre-germinated seed of a suitable host. After a successful growth period of three to six months, the host roots were evaluated for colonization and sporulation. Cultures showing colonized roots and spores were considered as successful cultures for raising monosporals and were considered to be pure when the spores isolated from them were morphotaxonomically similar to the voucher specimen prepared from the mother cultures that were used during the initiation of the monosporals (Figure 1). In case of CMCC/AM-2601, full sporulation state was attained after three cycles of the host plant.

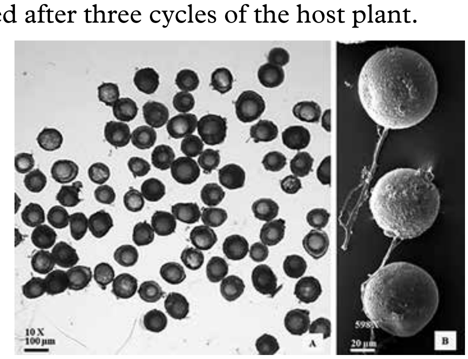

Figure 1 Compound microscopic (10×) and scanning electron microscopic (598×) images of identical spores obtained from monosporal culture of isolate CMCC/AM-2601

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A detailed morphotaxonomic description of this accession has been presented as adopted by various workers for identification.

Spore Morphology and Shape

Spores isolated from the monosporal cultures were borne singly or in small clusters of three or four in the extraradical region; they were devoid of sporocarps and each of them were suspended with a single subtending hyphae. Most of the spores were globose to sub-globose in shape and only a few of them were ellipsoidal and irregular. Mature spores were mostly pastel yellow to maize yellow in colour, whereas young spores appeared light yellow in colour. Scanning electron micrograph (SEM) of the spore surface revealed an outer slightly warty wall surface in mature spores without any prominent pits. The outermost surface of the spore is mucilaginous and appears rough with the organic debris adhered to it (Figure 2). The average diameter of the spore was found to be in a range of 50–(75.16)–120.15 µm (Figure 3).

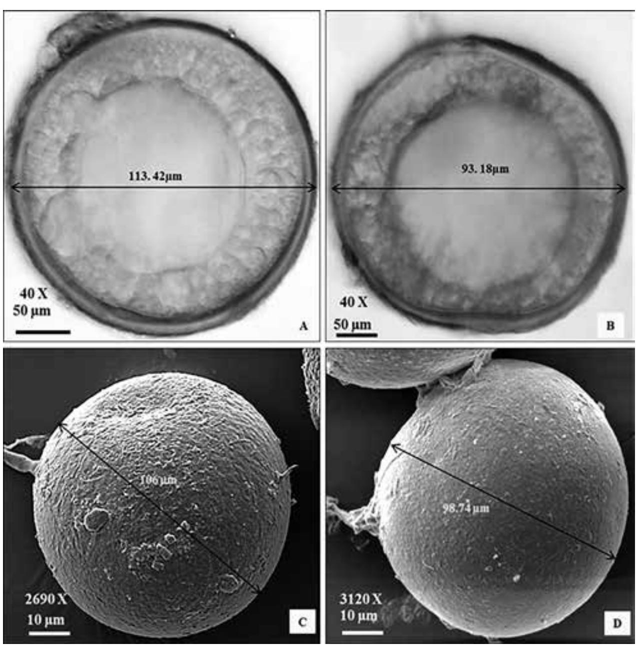

Figure 2 Compound and SEM of spores of CMCC/AM-2601 showing globose spore with single subtending hyphae. Spore mounted in PVLG (A) and PVLG: Melzer's reagents (B); SEM images of the spores (C and D)

Sub-Cellular Structure of Spore

Mature spores are composed of the following sub-cellular structures and wall layers:

- **Spore Wall Layer 1 (L-1):** The first layer of the spore designated as (L-1) is mucilaginous, hyaline, and roughened in mature spores. The average thickness of this outer wall layer is (0.5)–(0.75)–(0.95) µm thick. This layer is usually evanescent, deteriorates and gets sloughed off with the ageing of the spore, and thus, is rarely present in the spore wall of the mature specimen. This layer is highly mucilaginous and does not react in Melzer's reagent (Figure 4).

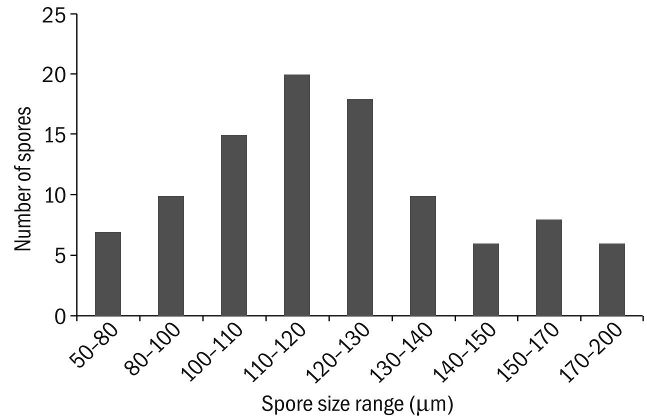

Figure 3 Analysis of spore diameters of 100 healthy spores obtained from one-year-old monosporal culture of CMCC/AM-2601

- **Spore Wall Layer 2 (L-2):** The inner wall after the first layer is a laminated, smooth, pastel yellow to maize yellow in colour. This layer remains prominent when the outer layer sloughs off in the mature spores. The wall thickness ranges from (1.5–) to 2.50 (–5.5) µm. This wall layer is a firm wall made of thin sub layers that tightly adhere to each other. This layer also does not show much reaction in Melzer's reagent and is the prominent wall layer of this species (Figure 4).
- **Spore Wall Layer 3 (L-3):** This is the innermost wall layer of the spore wall; this layer is flexible to semi-flexible in nature, hyaline, and sometimes

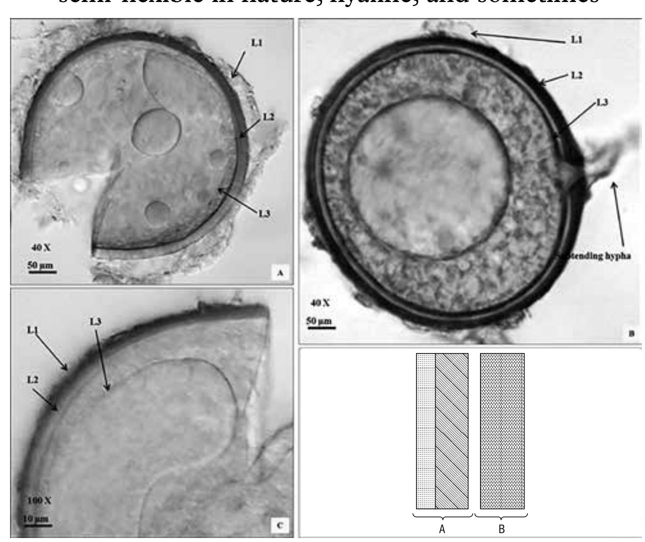

Figure 4 Compound microscopic images of spore wall layers of CMCC/AM-2601 after mounting in PVLG: PVLG (A), and Melzer's reagent (B and C). Murograph (Walker 1983) of the mature spore showing three distinct wall layers (D)

undetectable in immature spores. It is easily separated from L2; L3 is usually attached to the inner surface of subtending hyphal wall layer 2 close at the spore base to form a curved septum in the lumen of the subtending hypha. The third layer is the layer that reacts strongly with the Melzer's reagent and appears brownish-red in colour (Figure 4).

Subtending Hyphae

All the spores show intact, cylindrical, or slightly flared subtending hyphae, mostly hyaline and sometimes maize yellow. The width of the subtending hyphae at the point of attachment at the spore base ranges 4.18–(5.15)–6.5 µm. The hyphal wall of the subtending hyphae is hyaline and has three wall layers; however, only the innermost wall layer is continuous with the inner wall of the spore wall, L3 (Figure 5).

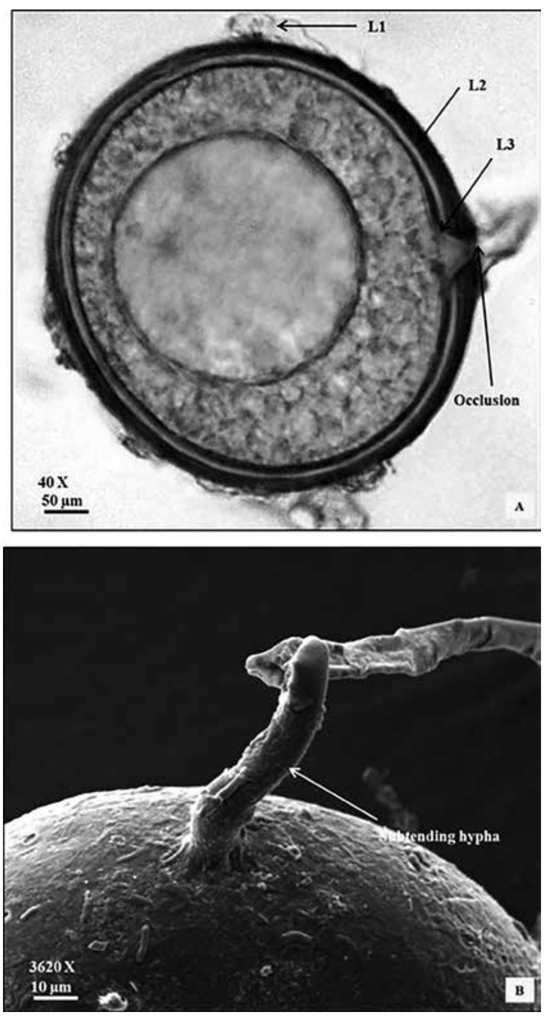

Figure 5 Compound microscopic images of spore of CMCC/AM-2601 showing cylindrical subtending hyphae after mounting it with PVLG: Melzer's reagent. The re-curved septum is continuous with the innermost layer of the laminated wall layer of the spore (A). SEM images of subtending hyphae (B)

Occlusion

Most of the spores in low resolution appear to have an open pore but higher magnification of the spore base reveals a thin curved septum, which is on an average 5–8 µm away from the point of attachment. The septum is continuous with the innermost sub-layers of the spore wall layer 3 (Figure 5A).

Mycorrhiza

Mycorrhiza structures such as arbuscules, extra and intraradical hypha, observed in *Sorghum bicolor* roots are deeply stained in ink vinegar. Root colonization assays showed the presence of both extraradical and intraradical hyphae. However, the extraradical hyphae are more abundant in specimen observed in pot cultures. Arbuscules are abundant and are dispersed unevenly through the root cortex. Intercalary vesicles are absent with exception of the extra-radicular region along the root surface, where it is present. Extra-radical hyphae were abundant and were usually seen bearing spores bearing or in a group of two to three (Figure 6).

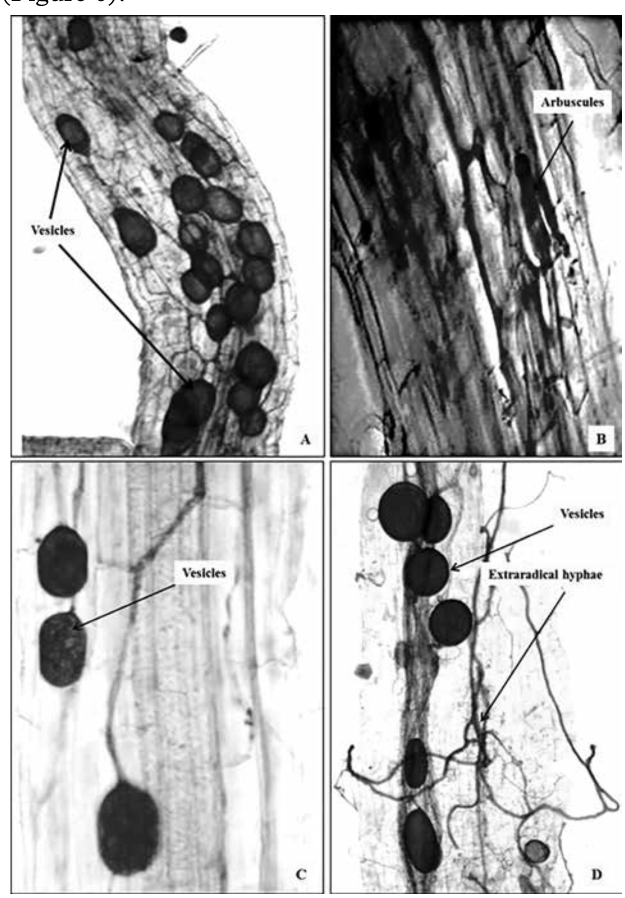

Figure 6 Compound microscopic images of roots of Sorghum bicolor stained in ink vinegar observed for root colonization by CMCC-AM-2601 showing extraradical and intraradical hypha and arbuscules and abundant vesicles in the cortical cells. Spores in the extraradical hyphae is also seen in small clusters

Conclusion and Classification Level

On the basis of above morphotaxonomic analysis of the accession CMCC/AM-2601, 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 or in loose aggregates of three or four with layered spore walls.
- Spore wall layer is composed of outer mucilaginous layer followed by one inner laminated layer and a flexible third layer that is continuous with the subtending hyphal wall.
- Spores are of varying shapes and sizes ranging from globose to sub-globose and sometimes irregular.
- Formation of both intraradical and extraradical hyphae and abundant vesicles and intra cellular arbuscules.

All these features suggest that the culture CMCC/AM-2601 belongs to the family Glomeraceae (Walker and Schüßler 2004).

Following are some of the unique morphotaxonomic features of the accession:

- Pastel yellow to maize yellow, globose, asexual spores produced singly with layered spore walls; spores are of varying shapes and sizes ranging from globose to sub-globose and sometimes irregular. Size ranges 50–(75.16)–120.15 μm.
- Spore wall layer is composed of outer mucilaginous layer, inner laminated layer, and a third flexible layer that is continuous with the subtending hyphal wall; L2 is the thickest and most prominent layer.
- Presence of intact, cylindrical, and slightly flared subtending hyphae. The width of the subtending hyphae at the point of attachment at the spore base ranges 4.18–(5.15)–6.5 μm.
- Presence of a thin curved septum, which is on an average 10–12 μm away from the point of attachment.
- Formation of both intraradical and extraradical hyphae and abundant vesicles and intracellular arbuscules.

The taxonomic feature of the accession CMCC/AM-2601 matches the characters of *Glomus drummondii* (Błaszkowski *et al.* 2006), a species originally described by Janusz Bqaszkowskia, Carsten Renkerb, and Francois Buscotb, in 2006, from north Poland.

The current taxonomic nomenclature of *G. drummondii* is *Claroideoglomus drummondii* (Błaszkowski *et al.* 2006; Schüßler, and Walker 2010).

Systematic Classification

Glomeromycota
Glomeromycetes
Glomerales
Glomeraceae
Glomus drummondii/Claroideoglomus drummondii

Conventional methods for identifying a species are usually based on taxonomic characters of an organism, assembling key characters, and comparing it 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

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Mycorrhiza Information Centre at TERI

Uttara Shankar, Project Associate, TERI

Research in the field of mycorrhiza is making remarkable progress as more and more scientists in the world over are turning to it and are engaged in exploring new and potential species of mycorrhiza that can be used as biofertilizers; their role in transport of phosphorous, nitrogen, and other micronutrients; their mass production, formulations; and subsequent field trials. Furthermore, research is also being carried out to study resistance of plants to biotic and abiotic stresses, such as drought resistance, disease resistance, and other benefits imparted by mycorrhiza to the plant species. In view of climate change and global warming, there is a necessity to evolve suitable mycorrhizal strains that can adapt to changing environments, soil conditions, agro-climatic zones, geographical locations, host complementarity so as to boost crop production. Suitable mycorrhiza can be identified for reclamation of waste lands, mine soils, and non-productive soils.

Data generated by all these endeavours needs to be made accessible to those interested in mycorrhizal research. Moreover, mycorrhiza information is often disseminated through wide range of publications, which sometimes makes the process of retrieving information difficult and/or time consuming. So, there is a need to put in place a specialized centre that will be a storehouse of the information on mycorrhiza, which would be of immense help in continuously disseminating the latest research findings to mycorrhiza scientists and also to fill up the gap in current knowledge availability. This will keep all the researchers, agriculturists, foresters, and other stakeholders abreast with the modern trends and frontline research activity going on in the field of mycorrhiza and its prospecting.

TERI with support from the Department of Biotechnology, Government of India, has set up a specialized information centre on Mycorrhiza at TERI, New Delhi. The centre aims at functioning as a specialized centre for collection, compilation, and dissemination of information and resources on mycorrhiza; thereby promoting resource sharing, networking, and disseminating knowledge. To meet these objectives, the centre has set up two broad platforms, viz.

1. The specialized reference centre, set up at TERI, New Delhi, is open to users for reference, research, and exploring the collection. The centre offers a range of information resources and facilities including computer systems with Internet access for users, books, journals, and other literature on mycorrhiza.
2. A dedicated project website <http://mycorrhizae.org.in/> containing databases, directories, publications, and other information literature and resources on mycorrhiza.

Other Services within the Centre

The mycorrhiza network publishes, since 1988, *Mycorrhiza Newsletter* on a quarterly basis to provide a forum for dissemination, acquisition, interaction, and communication of scientific information on mycorrhizal research and activities. The newsletter presents original research finding papers and, so far, has published over 400 articles from eminent scientists covering the biology, ecology, and other related aspects of mycorrhiza, including biodiversity and conservation of mycorrhizae. Other components encompassing the newsletter include notes on important breakthroughs; brief accounts of new approaches and techniques; research activities highlighting the Centre for Mycorrhiza Culture Collection; forthcoming events on mycorrhiza and related events; important references of research papers published in different national and international journals. The newsletter caters to the needs of young and enthusiastic workers in the field of mycorrhiza research, including farmers, agriculturists, foresters, policymakers, besides updating their knowledge about understanding of mycorrhizae at national and global level.

Submissions for Mycorrhiza News

a. *Research findings articles:* Under this column appear short notes on important breakthroughs/significant achievements in original research of high calibre in the field of mycorrhizae, which have not yet been published.

b. *New approaches:* Brief accounts of new techniques, modifications of available techniques, new applications of other known techniques, etc. in mycorrhiza research that have been published in reputed journals during the last two or three years may be submitted for publication in *Mycorrhiza News.*

c. *News and events of common interest* such as seminars/workshops/conferences attended, brief summaries of current research, etc. may be communicated to us for future issues of the *Mycorrhiza News.*

Paper Submission Guidelines

You may write about three–four-page-long manuscript with two figures, two tables, and should be accompanied by a brief of the significance. Submit your manuscript as email attachment to: uttara.shankar@teri.res.in.

Outreach Activities

The mycorrhiza network organizes workshops, training programmes, and conferences with the objectives of creating a forum for interaction among mycorrhiza research professionals and to keep abreast of the latest developments in the field.

Brainstorming Session

A brainstorming session on the 'Role of Mycorrhiza in Sustainable Agriculture and Forestry' is being organized on Wednesday, February 15, 2017, at India Habitat Centre, Lodhi Road, New Delhi. Participation of stakeholders, especially agriculturists involved in organic farming, scientists, young researchers, faculty, and students are encouraged in the workshop. The objective is to familiarize participants with the mycorrhiza fungi and their application including technology; procedures involved in the production of arbuscular mycorrhizal fungus (AMF) inoculum and their utility as biofertilizer; enabling participants to assess the quality of AMF inoculum and their produce or purchase; application of mycorrhizal inoculum in agriculture and forestry. Besides, a short session for students and faculty will also be held to bring awareness and inculcate interest among the youth regarding the role of mycorrhiza and fertilizer technologies.
For early registration for the workshop, please contact Uttara Shankar (uttara.shankar@teri.res.in) or Reeta Sharma (reetas@teri.res.in).

Centre for Mycorrhiza Culture Collection

The Mycorrhiza Network at TERI has developed a Database of Cultures to help researchers obtain information on specific cultures of interest depending upon the availability. The database houses and maintains cultures from different agro-ecological zones of the country and has an impressive collection of over 600 isolates of which 257 are EM isolates and over 300 are AM fungi. The information in the database includes the Germplasm Bank Code against each fungus name (genus and species). For more information, see <http://mycorrhizae.org.in/cmcc/>

Database of World Mycorrhiza Literature

The Mycorrhiza Information Centre has developed a web-based database of mycorrhiza literature with objectives of facilitating access to current research findings and development in the field of mycorrhiza and promoting research among scientists, agriculturists, mycorrhizologists, and students. The database contains bibliographic information and abstracts on mycorrhiza-related literature and has over 5,200 classified references published since 2003 from national and international journals <http://mycorrhizae.org.in/index.php?option=com_papers>.

Experts' Database

The centre has developed a directory of experts and scientists who are engaged in mycorrhiza research. The objective is to create a network of scientists associated directly with research on mycorrhizae as also to identify global centres and institutions where such research is being carried out.

The Directory has been developed based on the information collected through a questionnaire. Based on the responses received, the directory will be strengthened with details of mycorrhiza scientists. The directory is considered to be an on-going activity with new additions continually updating this directory. The directory has been made accessible through the Mycorrhiza Network website and will help Mycorrhiza scientists to communicate among themselves and update their CVs. The directory, with a user-friendly front-end, features the following search facilities:

- By expert
- By organization
- By principal fields of interest (category and subject)
- By combination of one or two of the above

Please send in your name, qualification, expertise, organization, contact address, and areas of interest to praveenb@teri.res.in for inclusion in the directory.

Join the Mycorrhiza Network

Scientists/researchers working in the area of mycorrhiza are invited to become members of the Network without any cost or obligations. The membership form may be filled in and submitted to uttara.shankar@teri.res.in.

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:

- *Soil Biology and Biochemistry*
- *Scientia Horticulturae*
- *Science of the Total Environment*
- *Chemosphere*
- *South African journal of Botany*
- *Agriculture, Ecosystems and Environment*
- *Chemosphere*
- *Flora - Morphology, Distribution, Functional Ecology of Plants*
- *Fungal Ecology*
- *Environmental and Experimental Botany*
- *Perspectives in Plant Ecology*
- *Plant Science*
- *Agriculture and Natural Resources*
- *Journal of Applied Research on Medicinal and Aromatic Plants*
- *Journal of Plant Physiology*
- *Applied Soil Ecology*
- *Ecological Engineering*

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)
Averill C*. 2016	**Slowed decomposition in ectomycorrhizal ecosystems is independent of plant chemistry** *Soil Biology and Biochemistry* **102***:52–54* [*5 Cummington St, Boston University, Boston, MA 02215, USA, E-mail: caverill@bu.edu]
Bizabani C, Fontenla S, Dames J F*. 2016	**Ericoid fungal inoculation of blueberry under commercial production in South Africa** *Scientia Horticulturae* **209**:173–177 [*Department of Biochemistry and Microbiology, Rhodes University, P.O. Box 94, Grahamstown 6140, South Africa, Email: j.dames@ru.ac.za]
Cao j, Wang C*, Ji D. 2016	**Improvement of the soil nitrogen content and maize growth by earthworms and arbuscular mycorrhizal fungi in soils polluted by oxytetracycline** *Science of the Total Environment* **571**:926–934 [*College of Resources and Environmental Sciences, China Agricultural University, Beijing 100193, China, Email: wangchong@cau.edu.cn]
Chen L, Zhang D, Yang W, Liu Y, Zhang L, Gao S*. 2016	**Sex-specific responses of *Populus deltoides* to *Glomus intraradices* colonization and Cd pollution** *Chemosphere* **155**:196–206 [*Institute of Ecological Forestry, Sichuan Agricultural University, Chengdu 611130, China, Email: shun1220@yahoo.com]
Chu X T, Fu J J, Sun Y F, Xu Y M, Miao Y J, Xu Y F*, Hu T M. 2016	**Effect of arbuscular mycorrhizal fungi inoculation on cold stress-induced oxidative damage in leaves of *Elymus nutans* Griseb** *South African journal of Botany* **104**:21–29 [*Department of Grassland Science, College of Animal Science and Technology, Northwest A&F University, Yangling, Shaanxi Province 712100, P.R. China, Email: xuyuefei1980@163.com]
Cobb A B*, Wilson G W T, Goad C L, Bean S R, Kaufman R C, Herald T J, Wilson J D. 2016	**The role of arbuscular mycorrhizal fungi in grain production and nutrition of sorghum genotypes: Enhancing sustainability through plant-microbial partnership** *Agriculture, Ecosystems and Environment* **233**:432–440 [*Oklahoma State University, 008C AGH, Stillwater, OK 74078, USA, Email: abcobb@okstate.edu]
Dhawi F, Datta R*, Ramakrishna W. 2016	**Mycorrhiza and heavy metal resistant bacteria enhance growth, nutrient uptake and alter metabolic profile of sorghum grown in marginal soil** *Chemosphere* **157**:33–41 [*Biological Sciences Department, Michigan Technological University, Houghton, MI, USA, Email: rupdatta@mtu.edu]

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)
Fracchia S*, Aranda-Rickert A, Rothen C, Sede S. 2016	**Associated fungi, symbiotic germination and in vitro seedling development of the rare Andean terrestrial orchid *Chloraea riojana*** *Flora - Morphology, Distribution, Functional Ecology of Plants* **224**:106–111 [*Centro Regional de Investigaciones Científicas y Transferencia Tecnológica, CRILAR- CONICET, Entre Ríos y Mendoza, 5301 Anillaco, La Rioja, Argentina, Email: sebafrac@yahoo.com.ar]
Fransson P*, Andersson A, Norström S, Bylundb D, Bent E. 2016	**Ectomycorrhizal exudates and pre-exposure to elevated CO_2 affects soil bacterial growth and community structure** *Fungal Ecology* **20**:211–224 [*Uppsala BioCenter, Department of Forest Mycology and Plant Pathology, Swedish University of Agricultural Sciences, Uppsala, Sweden, Email: petra.fransson@slu.se]
Jansa J*, Řezáčová V, Šmilauer P, Oberholzer H-R, Egli S. 2016	**Root colonization of bait plants by indigenous arbuscular mycorrhizal fungal communities is not a suitable indicator of agricultural land-use legacy** *Agriculture, Ecosystems and Environment* **231**:310–319 [*Laboratory of Fungal Biology, Institute of Microbiology, Academy of Sciences of the Czech Republic, 142 20 Prague, Czech Republic, Email: jansa@biomed.cas.cz]
Kilpeläinen J*, Vestberg M, Repo T, Lehtoa T. 2016	**Arbuscular and ectomycorrhizal root colonisation and plant nutrition in soils exposed to freezing temperatures** *Soil Biology and Biochemistry* **99**:85–93 [*University of Eastern Finland, School of Forest Sciences, P.O. Box 111, FI-80101 Joensuu, Finland, Email: jouni.kilpelainen@uef.fi]
Kodre A*, Arčon I, Debeljak M, Potisek M, Likar M, Vogel-Mikuš K. 2016	**Arbuscular mycorrhizal fungi alter Hg root uptake and ligand environment as studied by X-ray absorption fine structure** *Environmental and Experimental Botany* **133**:12–23 [*University of Ljubljana, Faculty of Mathematics & Physics, Jadranska 19, Ljubljana, Slovenia]
Leopold D R*. 2016	**Ericoid fungal diversity: Challenges and opportunities for mycorrhizal research** *Fungal Ecology* (Available online 5 August 2016) [*Stanford University, Department of Biology, 371 Serra Mall, Stanford, CA 94305-5020, USA, Email: dleopold@stanford.edu]
Menzel A*, Hempel S, Manceur A M, Götzenberger L, Mooraf M, Rillig M C, Zobelf M, Kühn I. 2016	**Distribution patterns of arbuscular mycorrhizal and non-mycorrhizal plant species in Germany** *Perspectives in Plant Ecology* **21**:78–88 [*Helmholtz Centre for Environmental Research – UFZ, Department of Community Ecology, Theodor-Lieser-Str. 4, 06120 Halle (Saale), Germany, Email: andreas.menzel@ufz.de]
Merlos M A, Zitka O, Vojtech A, Azcón-Aguilar C, Ferrola N*. 2016	**The arbuscular mycorrhizal fungus *Rhizophagus irregularis* differentially regulates the copper response of two maize cultivars differing in copper tolerance** *Plant Science* **253**:68–76 [*Departamento de Microbiología del Suelo y Sistemas Simbióticos, Estación Experimental del Zaidín, CSIC, Profesor Albareda 1, 18008 Granada, Spain, Email: nuria.ferrol@eez.csic.es]
Nakmee P S*, Techapinyawat S, Ngamprasit S. 2016	**Comparative potentials of native arbuscular mycorrhizal fungi to improve nutrient uptake and biomass of *Sorghum bicolor* Linn** *Agriculture and Natural Resources* **50**(3):173–178 [*Faculty of Science at Sriracha, Kasetsart University, Sriracha Campus, Chonburi 20230, Thailand, Email: pattarawadee@src.ku.ac.th]

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)
Pankaj U, Verma S K*, Semwal M, Verma R K. 2016	**Assessment of natural mycorrhizal colonization and soil fertility status of lemongrass [(*Cymbopogon flexuosus*, Nees ex Steud) W. Watson] crop in subtropical India** *Journal of Applied Research on Medicinal and Aromatic Plants* (Available online 19 October 2016) [*Department of Soil Science, CSIR-Central Institute of Medicinal and Aromatic Plants (CIMAP), Lucknow 226015, India]
Schweiger P F*. 2016	**Nitrogen isotope fractionation during N uptake via arbuscular mycorrhizal and ectomycorrhizal fungi into grey alder** *Journal of Plant Physiology* **205**:84–92 [*Department of Microbiology and Ecosystem Science, Division of Terrestrial Ecosystem Research, University of Vienna, Althanstrasse 14, A-1090 Vienna, Austria, Email: peter.schweiger@univie.ac.at]
Sabella E*, Nutricati E, Aprile A, Miceli A, Negro C, Rampino P, Lenucci M, Bellis L D. 2016	***Tuber borchii Vitt*. mycorrhiza protects *Cistus creticus* L. from heavy metal toxicity** *Environmental and Experimental Botany* **130**:181–188 [Dipartimento di Scienze e Tecnologie Biologiche ed Ambientali, Università del Salento, via Prov. le Monteroni 165, 73100 Lecce, Italy. Email: erika.sabella@unisalento.it]
Sowik I*, Borkowska B, Markiewicz M. 2016	**The activity of mycorrhizal symbiosis in suppressing *Verticillium wilt* in susceptible and tolerant strawberry *(Fragaria x ananassa Duch.)* genotypes** *Applied Soil Ecology* **101**:152–164 [*Research Institute of Horticulture, Pomologiczna 18, 96-100 Skierniewice, Poland, Email: iwona.sowik@inhort.pl]
Swaty R*, Michael H M, Deckert R, Gehring C A. 2016	**Mapping the potential mycorrhizal associations of the conterminous United States of America** *Fungal Ecology* (Available online 7 June 2016) [*The Nature Conservancy's LANDFIRE Team, Wilmette, IL 60091, USA]
Weisany W*, Raei Y, Ghassemi-Golezani K. 2016	***Funneliformis mosseae* alters seed essential oil content and composition of dill in intercropping with common bean** *Fungal Ecology* **79**:29–38 [*Department of Plant Ecophysiology, Faculty of Agriculture, University of Tabriz, Iran, Email: Weria.Wisany@gmail.com]
Wu S, Zhang X, Chen B*, Wu Z, Li T, Hu Y, Sun Y, Wang Y. 2016	**Chromium immobilization by extraradical mycelium of arbuscular mycorrhiza contributes to plant chromium tolerance** *Environmental and Experimental Botany* **122**:10–18 [*State Key Laboratory of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, People's Republic of China, Email: bdchen@rcees.ac.cn]
Zhang S*, Wang L, Ma F, Zhang X, Fu D. 2016	**Arbuscular mycorrhiza improved phosphorus efficiency in paddy fields** *Ecological Engineering* **95**:64–72 [*Department of Municipal Engineering, School of Civil Engineering, Southeast University, Nanjing, 210096, China, Email: zhangshujuan525@sina.com]
Zou Y-N*, Chen X, Srivastav A K, Wangd P, Xiang L, Wu Q-S. 2016	**Changes in rhizosphere properties of trifoliate orange in response to mycorrhization and sod culture** *Applied Soil Ecology* **107**:307–312 [*College of Horticulture and Gardening, Yangtze University, Jingzhou, Hubei 434025, China]

Workshop Announcement
Role of Mycorrhiza in Sustainable Agriculture and Forestry

The Mycorrhiza Network at The Energy and Resources Institute (TERI), with support from the Department of Biotechnology, Government of India, is organizing a brainstorming session on the topic "**Role of Mycorrhiza in Sustainable Agriculture and Forestry**," on February 15, 2017, at 10.00 a.m. at Juniper Hall, India Habitat Centre, Lodhi Road, New Delhi.

Researchers and budding scientists (engaged in the field of mycorrhiza research), agriculturists (involved in organic farming), students, faculty, and other stakeholders are invited to take part in the event.

The objective is to familiarize participants with mycorrhiza fungi and their application including technology, procedures involved in the production of mycorrhizal inoculum and their utility as bio-fertilizer, to enable participants to assess the quality of mycorrhizal inoculum and their produce or purchase; and application of mycorrhizal inoculum in agriculture and forestry.

Besides, a short session for students and faculty will also be held to bring awareness and inculcate interest among the youth regarding the role of mycorrhiza and fertilizer technologies.

PROGRAMME

09:00	**Registration** (Registration is free on first-come first-serve basis)
10:10	**Welcome Address** Mr Prabir Sengupta, Director, Knowledge Management Division, TERI
10:20	**Inaugural Address** Dr T Madhan Mohan, Adviser, Department of Biotechnology, Government of India
10:30	**Special Address: Introduction to Mycorrhiza and Its Utility** Dr Alok Adholeya, Honorary Adviser, Biotechnology and Bioresources Division, TERI
11:00	**Coffee Break**
11:15	**Mycorrhiza—Future Vision—Interactive Session with Students and Faculty** Dr Alok Adholeya, Honorary Adviser, Biotechnology and Bioresources Division, TERI; Prof. C Manoharachary, Emeritus Scientist, CSIR
SESSION I	
12:00	**Mycorrhiza in Sustainable Agriculture, Horticulture and Forestry** Prof. D J Bagyaraj, INSA Hon. Scientist; Chairman, Centre for Natural Biological Resources and Community Development, Bangalore
12:30	**Commercialization of AM Fungi and Biofertilizer** Prof. C Manoharachary, Emeritus Scientist, CSIR
13:00	**Role of Ectomycorrhizae in Forestry Development** Prof. N Raaman, Director, Centre for Advanced Studies in Botany, University of Madras
13:30	**Scope and Limitations of AM Bio-fertilizers** Prof. B F Rodrigues, Department of Botany, University of Goa
14:00	**Lunch**
SESSION II	
14:45	**Presentation of the TERI Mycorrhiza Network**
15:00	**Presentation of Select Case Studies/Interaction with Participants**
15:30	**End of Session**

For registration, please contact
Ms Uttara Shankar
Workshop Coordinator, Mycorrhiza Network
Email: uttara.shankar@teri.res.in
Telephone: 24682100 or 41504900 Extn 2728

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Atlanta, Georgia, **USA**
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Fax: +1-650-618-1417
Email: environmentalmicrobiology@microbiologyconferences.org
Website: http://environmentalmicrobiology.conferenceseries.com/conference-brochure.php

Washington, The District of Columbia, **USA**
19–22 February 2017

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Tel.: +1 (919) 668-1928
Fax: +1(919) 684-8749
Email: aiea@duke.edu
Website: http://www.aieaworld.org/annual-conference

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Email: stemcell@geneticconferences.com
Website: http://stemcell.conferenceseries.com/registration.php

Havana**, Cuba**
10–14 April 2017

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Email: seminariointernacional2017@inisav.cu
Website: www.inisav.cu

Niagara Falls, Ontario**, Canada**
4–8 June 2017

IOBC-WPRS Working Group "Integrated Control in Protected Crops, Temperate Climate"

Email: questions@iobccanada2017.ca
Website: http://iobccanada2017.ca

San Francisco, California, **USA**
29 July–4 August 2017

2017 International Congress on Membranes and Membrane Processes (ICOM 2017)
University of Toledo, MS 305, 2801 West Bancroft Street, Toledo, OH USA

Tel.: +1.419530-8088
Email: chairs@icom2017.org
Website: http://www.icom2017.org/registration.html

Prague, **Czech Republic**
30 July–4 August 2017

ICOM 9: Ninth International Conference on Mycorrhiza
Conference Secretariat, GUARANT International, Na Pankráci 17, 140 21 Prague 4, Czech Republic

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