

Mycorrhizal integration across continents and scales

The International Conference on Mycorrhiza (ICOM) provides a global forum for mycorrhizal scientists to exchange exciting new discoveries and ideas about mycorrhizal symbioses. The weeklong event under ICOM8 attracted over 500 participants comprising mycorrhizal geneticists, taxonomists, physiologists, ecologists, inoculum producers and land managers from more than 50 countries, making it a truly global conference. The theme of the conference 'Mycorrhizal integration across continents and scales' stressed the importance of one of the most widespread and fascinating symbioses in different ecosystems across the globe. Mycorrhizas integrate plant and fungal kingdoms creating a complex community that provides soil structural stability, defines ecosystem properties by providing underground highways for nutrient transfer among unrelated plants, improves plant health and function as an interface between living roots and mineral soil.

Reflecting on the wisdom of 'past giants' in the field of mycorrhizal science, Jim Trappe (Department of Ecosystems and Society, Oregon State University, USA), a living legend, delivered the opening keynote talk on the history of mycorrhizal research and development focusing, particularly, on two giants: Albert Bernhard Frank (1839–1900) and Johannes Botvid Elias Melin (1889–1979). He mentioned that mycorrhizal history starts with Robert Hartig, Carlo Vittadini, Isobel Buckmann and J. L. E. Boudier and culminates with Frank, who was instrumental in unifying the mycorrhizal concept.

Maarja Õpik (University of Tartu, Estonia), the curator of the database www.maarjAM.botany.ut.ee, outlined the importance of understanding the taxonomic and functional diversity of arbuscular mycorrhizal fungi (AMF) along natural gradients and response of AMF to climate change and changing land use. Although AMF originated about 400 mil-

lion years ago in the palaeozoic era, the global biogeography of these symbionts remains largely unknown¹. Based on fossil evidence from the Rhyne Chert, S. L. Stürmer (Universidade Regional de Blumenau, Brazil) showed that pandemism is present in all major AMF clades (Acaulosporaceae, Gigasporaceae, and Glomeraceae), and endemism is a rare phenomenon. Dirk Redecker (Universite de Bourgogne, France) highlighted recent advances and perspectives of glomeromycotan phylogeny and its importance in the studies of AMF ecology². He pointed to the fact that the lack of sequence data for majority of the glomeromycotan members is a major hindrance for the construction of a comprehensive multilocus dataset. In an effort to improve molecular genetics and genomic analysis of AMF isolates, Redecker and his team has established 'The International Bank for the Glomeromycota'. C. Manoharachary (Osmania University, Hyderabad) provided a novel perspective of glomeromycotan taxonomy in the light of Melbourne Code-2013. Elucidation of proteomes of closely as well as distantly related lineages has the potential to clarify phylogenetic relationships. G. R. Boyce (Thompson Institute for Plant Research, USA) used spore-level proteome analysis to infer phylogenetic relationships among three *Rhizophagus* species of Glomeromycota.

In recent times, there has been an increase in the number of AMF ecological studies due to the advent of newer techniques like next generation sequencing (NGS). However, NGS technology has the potential for biases during amplification and sequencing, affecting results and conclusions³. To overcome these shortcomings, C. P. Egan (Biology University of British Columbia, Canada) developed a dual-end sequencing/indexing technique for AMF that can accurately identify and quantify AMF taxa without introducing biases. He was awarded the Harley Medal for best student oral presentation.

ICOM8 showcased recent advancement in mycorrhizal transcriptomic studies and the diverse role played by transcriptomes in understanding the origin and functioning of symbiosis. A.

Kohler (INRA, France) explained the role played by mycorrhiza-induced small secreted proteins (MiSSPs) for symbiosis formation and fruiting body development. Strigolactones (SLs) are essential components of root exudates that induce AMF hyphal branching, thereby favouring root colonization. L. Lanfranco (University of Torino, Italy) gave a detailed presentation on how arbuscular mycorrhiza (AM) perceive SLs and showed various molecular determinants involved in SLs response in AMF. A. M. Schmitz (Boyce Thompson Institute for Plant Research, NY, USA) showed that plant-secreted lysin motif (LysM) may play a role in suppressing pattern-triggered immunity in plants and thus AMF are able to avoid the first level of plant defence during AM symbiosis⁴. Florian Walder (Institute for Sustainability Sciences, Switzerland) showed that resource exchange in AM symbiosis is not reciprocal, thereby refuting the much established reciprocal trade and biological market theory⁵.

The role of ectomycorrhizal fungi (ECM) in organic matter decomposition has been a subject of debate. Most of the researchers believed that ECM had lower enzyme activities than other saprophytes and therefore, the role of these fungi in nutrient cycling was less appreciated. F. Rineau (Universiteit Hasselt, Belgium) shed new light on the involvement of ECM in soil organic matter decomposition by a redox mechanism somewhat similar to saprophytic brown-rot fungi⁶. These new insights provide a basis and references for further clarifying the role of ECM fungi in the recycling of the organic matter.

Conversion of pristine forests to agricultural lands is one of the leading causes of biodiversity loss worldwide. Working in the Indo-Burma biodiversity hotspot region, D. Sharmah (Jawaharlal Nehru Rajkeeya Mahavidyalaya, Port Blair) found that AMF diversity is not significantly affected by the slash-and-burn agricultural land-use practices practised by the ethnic hilly tribes and, therefore, it could be a component of a tropical forest 'conservation-agriculture matrix'⁷. For scientists and land managers involved in conservation and land

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management practices, a genetic-based understanding of communities and ecosystem is a prerequisite that provides sound information about specific plant genotypes and genetic-based interactions (e.g. mycorrhizae/plant), which can be potentially used in various restoration programmes⁸. T. G. Whitham (Northern Arizona University, USA) talked about restoration success stories and stressed the need to select the right plants in the restoration programme because a locally adapted plant may be maladapted tomorrow due to climate change. M. R. Maltz (University of California, USA) outlined the importance of mycorrhizal inocula sourced from reference ecosystems compared to commercial sources in restoration projects⁹. She was awarded the Mycorrhiza Prize for the best student poster.

M. K. Firestone (University of California, Berkeley, USA) emphasized the importance of integrating AMF with other members of the soil ecosystem, particularly bacteria and fungi, and showed that AMF influence microbial assemblages in the hyposphere.

The future of mankind depends on sustainable use of resources by the ever-burgeoning population which is expected to reach 9.6 billion by 2050. The use of

AMF can meet these challenges to a great extent, providing economic and environmental benefits in the future. A. Adholeya (The Energy and Resources Institute, New Delhi) found that seed priming and encapsulation can promote AMF colonization and increase nutrient acquisition by crops, thus, potentially improving the quality and quantity of the produce. Future research synthesizing these findings will help in better understanding the practical use of AMF in agriculture, forestry and restoration projects, which is fundamental for meeting future global food demands, mitigating climate change and developing conservation strategies. We hope that the theme of the next ICOM 'Mycorrhizal functioning: from wilderness to megacities', to be held in 2017 in Prague, Czech Republic, will provide the right platform and framework to discuss and find answers to human-induced environmental crises of the present time.

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MEETING REPORT

Earthquake hazard*

A one-week training programme was held recently to impart an understanding of earthquake science and of the methodologies to quantify earthquake hazard. The programme included lectures, tutorials with hands-on exercises and field studies. Eminent academicians and scientists from India and abroad mentored the participants from different parts of India who attended the programme.

The topics covered during the training programme included continental tectonics, seismology, GPS geodesy and its

application to the study of continental deformation, active tectonics of the Himalaya, earthquake hazard and its impact on society, and geopolitics. Special focus was given to the recent Nepal earthquake as a case study to understand the current state of knowledge. James Jackson summarized the training programme through his final lecture on 'Building resilience to earthquakes along the Alpine Himalayan Belt'.

Participants were given an opportunity to present their ongoing research in the form of oral and poster presentations. These encompassed a variety of topics which included Seismotectonics of the Eastern Himalayan and Indo-Burman Plate boundary systems; active deformation and crustal structure beneath the Sikkim Himalaya; uncertainty analysis of Shuttle Radar Topography Mission

(SRTM)-derived quantitative topographic profiles using Real Time Kinematic Global Navigation Satellite System data (RTK-GNSS); crustal and upper mantle studies in J&K Himalaya; the 2013 Minab earthquake, SE Iran; coupling of climate and tectonics for formation of Late Quaternary Ravi river terraces in Chamba region, NW Himalaya; geodynamics of the Andaman Sea with special reference to the Andaman Back Arc Basin inferred from the ocean bottom seismometer data and application of nonlinear techniques on geochemical data – a basic approach for earthquake precursor. The mentors were impressed by the quality and motivation of the students, and were pleased to mentor and interact with them.

The training programme highlighted the present state of earthquake science in

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