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EDITORIAL

19th International Meeting on *Frankia* and Actinorhizal Plants

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Abstract It has been 40 years since the first meeting dedicated to *Frankia* and actinorhizal plants, which was held at Petersham, Massachusetts (reported in Torrey and Tjepkema, 1979). Since then biennial meetings have been organised and held in different venues around the globe (Table 1). The most recent meeting, the "19th International Meeting on *Frankia* and Actinorhizal Plants", organised in Hammamet, Tunisia from 17th to 19th of March, 2018, gathered scientists from Algeria, Argentina, Belgium, China, Egypt, France, India, Portugal, Senegal, Sweden, UK, USA and Tunisia. The event was a stimulating opportunity for active researchers to share many advances since the previous meeting held in Montpellier, France (Franche et al. 2016) and to discuss new perspectives in this research field.

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Since 2016, the availability of many *Frankia* genomes (Tisa et al. 2016) covering the major *Frankia* clades (Gtari et al. 2013), and the incorporation of comparative genome data, omniLog phenoarrays, morphology, chemotaxonomy and host plant range knowledge have enabled species definitions according to conventional nomenclature. Gtari et al. (2019) summarise current *Frankia* taxonomy and provide keys features of the 11 species with validly published names that have been proposed within the genus *Frankia*. In this regard Nouioui et al. (2019) described a new species *Frankia torreyi* with $CpI1^T$, the first member of the genus *Frankia* isolated in axenic condition (Callaham et al. 1978), as type strain.

Establishing a *Frankia* actinorhizal symbiosis requires mutual recognition and specific molecular communication between the two partners. While most of symbiotic signaling pathways known for legume and mycorrhizal symbioses have counterparts in the actinorhizal symbiosis (Hocher et al. 2006, 2011; Demina et al. 2013; Griesmann et al. 2018), *Frankia* nodulating factor is different from known rhizobial and mycorrhizal chitin derivative factors (Cérémonie et al. 1998, 1999; Ghelue et al. 1997; Svistoonoff et al. 2010; Chabaud et al. 2016; Cissoko et al. 2018) and remains uncharacterised due to the continuing

Table 1 International meetings on *Frankia* and actinorhizal plants

Edition	Year	Place	Proceedings	Special issue
1	1978	Petersham, Massachusetts, USA	Torrey and Tjepkema (1979)	Botanical Gazette
2	1979	Corvalis, Oregon, USA	Gordon et al. (1979)	Oregon State University Press
3	1982	Madison, Wisconsin, USA	Torrey and Tjepkema (1983)	Canadian Journal of Botany
4	1983	Wageningen, The Netherlands	Akkermans et al. (1984)	Plant and Soil
5	1984	Québec, Canada	Lalonde et al. (1985)	Plant and Soil
6	1986	Umeâ, Sweden	Huss-Danell and Wheeler (1987)	Physiologia Plantarum
7	1989	Storrs, Connecticut, USA	Winship and Benson (1989)	Plant and Soil
8	1991	Lyon, France	Normand et al. (1992)	Acta Oecologica
9	1993	Okahune, New Zealand	Harris and Silvester (1994)	Soil Biology and Biochemistry
10	1995	Davis, California, USA	Berry and Myrold (1997)	Physiologia Plantarum
11	1998	Champaign; Illinois, USA	Dawson et al. (1999)	Canadian Journal of Botany
12	2001	Carry-le-Rouet, France	Normand et al. (2003)	Plant and Soil
13	2005	Durham, New Hampshire, USA	Tisa (2005)	Symbiosis
14	2006	Umeâ, Sweden	Sellstedt et al. (2007)	Physiologia Plantarum
15	2008	Bariloche, Argentina	Wall et al. (2010)	Symbiosis
16	2010	Porto, Portugal	Santos and Tavares (2012), Ribeiro et al. (2011)	Archives of Microbiology; Functional Plant Biology
17	2013	Shillong, India	Misra (2013)	Journal of Biosciences
18	2015	Montpellier, France	Franche et al. (2016)	Symbiosis

inablility to genetically manipulate *Frankia*. In this regard, Pesce et al. (2019) developed a colony PCR technique that provides a routine procedure for rapidly identifying *Frankia* strains that may expedite the process of identifying *Frankia* strains or potential transformants. In addition, Hocher et al. (2019) reported recent technical achievements for several actinorhizal species and major discoveries in *Frankia*-actinorhizal signaling pathways.

While the overall clustering of the four *Frankia* lineages remains conserved between each locus analysed with different levels of resolution (Gtari et al. 2013), the precise evolutionary history of the four clusters remains unclear and inconsistent. This topology is has been explored using a variety of approaches. In this context Sarkar et al. (2019) and Sen et al. (2019) used unusual phylogenetic approaches. Sarkar et al. (2019) selected 100 actinobacteria, including *Frankia,* and built a phylogenetic tree based on the presence and absence of protein domains. The resulting phylogeny clustered the actinobacteria mainly according to their niche rather than their taxonomic classification. Sen et al. (2019) reported a phylogenetic analysis based on putative carbohydrate active enzymes (CAZymes) that are capable of breaking complex polysaccharides into simpler forms. Phylogenetic and evolutionary analyses showed that, in symbiotic *Frankia* strains, CAZymes are evolving slower than the other potentially highly expressed genes, whereas similar genes from asymbiotic *Frankia* strains showed little variation in their evolutionary constraints compared to other potentially highly expressed genes.

Isolation of several new strains was a fascinating feature of the meeting. A contributed paper by Gueddou et al. (2019) reports a second Cluster-2 isolate, designated BMG5.30, which is able to reinfect its host plant. Its genome sequence shows that it is more closely related to that *Frankia coriariae* BMG5.1 than the two other *Frankia* genomes from *Datisca*. Based on comparative genomics, *Frankia* sp. strain BMG5.30 is a new member of the species *F. coriariae*. Ghodhbane-Gtari et al. (2019) reported the isolation of two non-*Frankia* actinobacteria from root nodules of *Casuarina glauca* growing in Tunisia that have been assigned to the genus *Nocardia* with one strain that is the type strain representing a new species designated *Nocardia casuarinae* (Ghodhbane-Gtari et al. 2014). The two strains have several important traits that benefit actinorhizal plants. Their ability to produce auxins, cause root hair deformation, and induce nodule-like structures with beneficial growth promoting effects on the development of the *C. glauca* plants supports this idea. Coinfection studies also showed that BMG51109 caused an earlier onset of nodulation.

A number of contributions dealt with the environmental biology of *Frankia*. Kucho et al. (2019) studied *Frankia* communities in disturbed land on Mt. Ontake following the 1984 earthquake that caused a devastating landslide using *nifH* amplicon sequences. The authors demonstrated that a diverse *Frankia* community was detected in the most advanced revegetation area, suggesting that revegetation positively affects *Frankia* diversity. Rehan et al. (2018) reported the mechanism of detoxification and reduction of selenite to elemental red selenium by *Frankia inefficax* strain EuI1c. The involvement of a periplasmic-binding protein homolog, putative sulfate ABC transporter and extracellular ligand-binding receptor was demonstrated.

Within the current and predicted scenarios of climate changes and human population growth, and their concomitant impact on the availability of arable land, actinorhizal plants should be seen as strong candidates to mitigate some of the negative impacts thanks to their mutualistic symbiosis. Ribeiro-Barros et al. (2019) reviewed the distribution, conservation and uses of actinorhizal species native to or introduced in Africa and their relevance for the developing economies of many African countries, which are highly sensitive to climate and anthropogenic disturbances.

Zhong et al. (2019) reviewed Chinese inoculation expertise aimed at improving *Casuarina* spp. survival and productivity, mainly in the “Great Green Wall” that represents vast plantations of Casuarina along 3000 km long and 0.5–5 km width on the coast fronting the South China Sea.

Finally we are thankful to all attendees to Hammamet for the friendly atmosphere and productive meeting, to the authors that contributed to this special issue and to the Frankiologists who acted as anonymous reviewers. A special thank is expressed to Editor-in-Chief Professor Iain Sutcliffe and the Editorial office of Antonie van Leeuwenhoek.

On to Japan-2020 for the next *Frankia*-actinorhizal plants meeting!

Conflict of interest The authors declare that they have no conflict of interest.

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