

## REVIEW

# Adventitious rooting of conifers: influence of biological factors

Maria Amely Zavattieri<sup>1</sup>  · Carla Ragonezi<sup>2</sup> · Krystyna Klimaszewska<sup>3</sup>

Received: 21 December 2015 / Accepted: 18 May 2016  
© Springer-Verlag Berlin Heidelberg 2016

**Abstract** Vegetative propagation of superior conifer trees can be achieved, e.g., through rooted cuttings or rooted microshoots, the latter predominantly through in vitro tissue culture. Both techniques are used to achieve rapid multiplication of trees with favorable genetic combinations and to capture a large proportion of the genetic diversity in a single generation cycle. However, adventitious rooting of shoots (cuttings) is often not efficient due to various problems, such as scarcity of roots and cessation of their growth, both of which limit the application of vegetative propagation in some conifer species. Many factors are involved in the adventitious rooting of shoots, including physical and chemical ones, such as plant growth regulators, carbohydrates, light quality, temperature and rooting substrates, or media [reviewed by Ragonezi et al. (*Trees* 24(6):975–992, 2010)]. The focus of this review is on biological factors, such as inoculations with *Agrobacterium rhizogenes*, plant-growth promoting rhizobacteria and

other endophytes, and mycorrhizal fungi, which were found to stimulate adventitious rooting. These microorganisms could contribute not only to adventitious root development but also to help in protecting conifer plants against pathogenic microorganisms, facilitate acclimation and transplanting, and contribute to more sustainable, chemical-free forests.

**Keywords** Biotization · Mycorrhization · Plant-growth promoting bacteria · Gymnosperms

## Abbreviations

|                 |  |
|-----------------|--|
| BnR             | Binucleate Rhizoctonia                         |
| DNA             | Deoxyribonucleic acid                          |
| ECM             | Ectomycorrhizal fungi or Ectomycorrhizas       |
| ERM or EMF      | Ericoid mycorrhizal fungi; Ericoid mycorrhizas |
| GA <sub>3</sub> | Gibberellic acid or Gibberellin A <sub>3</sub> |
| IAA             | Indole-3-acetic acid                           |
| IBA             | Indole-3-butyric acid                          |
| M               | Molar  |
| μM              | Micromolar                                     |
| MHB             | Mycorrhization helper bacteria                 |
| Mm              | Millimolar                                     |
| MS              | Murashige and Skoog (1962) culture medium      |
| NAA             | 1-Naphthaleneacetic acid                       |
| PGPR            | Plant-growth promoting rhizobacteria           |
| PGR             | Plant growth regulators                        |
| RSB             | Root-stimulating bacteria                      |
| Ri              | Root-inducing plasmid                          |
| t-DNA           | Transfer DNA                                   |
| Ti              | Tumor-inducing plasmid                         |
| TIBA            | 2,3,5-Triiodobenzoic acid                      |
| VAM             | Vesicular–arbuscular mycorrhizas               |

Communicated by M. Buckeridge.

✉ Maria Amely Zavattieri  
zavattieri@uevora.pt

<sup>1</sup> ICT-Instituto das Ciências da Terra, Universidade de Évora, Évora, Portugal

<sup>2</sup> Universidade Federal dos Vales do Jequitinhonha e Mucuri-UFVJM, Rodovia MGT 367, Km 583.5000, Alto da Jacuba, Diamantina, MG 39100-000, Brazil

<sup>3</sup> Natural Resources Canada, Canadian Forest Service, Laurentian Forestry Center, 1055 du PEPS, Stn. Sainte-Foy, P.O. Box 10380, Quebec, QC G1V 4C7, Canada