

The Biology of *Frankia* and Actinorhizal Plants

Christa R. Schwintzer and John D. Tjepkema

Department of Botany and Plant Pathology

University of Maine

Orono, Maine



Academic Press, Inc.

Harcourt Brace Jovanovich, Publishers

San Diego New York Boston London Sydney Tokyo Toronto

Contents

Dedication	v
Contributors	xv
Preface	xvii

1. Introduction

Dwight D. Baker and Christa R. Schwintzer

I. Frankiae	3
II. Actinorhizal Root Nodule Symbioses	7
III. Distribution of Actinorhizal Plants	8
IV. Practical Uses of Actinorhizal Plants	11
References	11

2. Discoveries, Discussions, and Trends in Research on Actinorhizal Root Nodule Symbioses before 1978

Anton Quispel

I. The Classical Period until the End of the Nineteenth Century	17
II. The Intermediary Period from the Beginning of the Twentieth Century until 1950	19
III. The Modern Period from 1950 to 1978	21
References	28

3. Systematics, Isolation, and Culture of *Frankia*

Mary P. Lechevalier and Hubert A. Lechevalier

I. Systematics	35
II. Isolation of <i>Frankia</i>	44
	ix

III. Culture of <i>Frankia</i>	52
References	56
4. The Infection Process and Nodule Development	
<i>Alison M. Berry and Leslie A. Sunell</i>	
I. Infection Process	61
II. Nodule Development	68
III. Regulation of Infection and Nodule Development	77
IV. Summary	79
References	79
5. Cross-Inoculation Groups within <i>Frankia</i> and Host– Endosymbiont Associations	
<i>John G. Torrey</i>	
I. Introduction	83
II. Methods of Testing Host–Microsymbiont Associations	83
III. Evidence Concerning Host Specificity of <i>Frankia</i> Strains and the Phenomenon of Cross- Inoculation Infectivity	92
References	103
6. Physiology and Biochemistry of <i>Frankia</i> in Culture	
<i>David R. Benson and Nancy A. Schultz</i>	
I. Introduction	107
II. General Cultural Characteristics	108
III. Carbon Metabolism of <i>Frankia</i> in Culture	110
IV. Nitrogen Metabolism	115
V. Protection of Nitrogenase from Oxygen in Culture	122
VI. Conclusions	123
References	124
7. The Physiology of Actinorhizal Nodules	
<i>Kerstin Huss-Danell</i>	
I. Introduction	129
II. Nodule Dormancy	129
III. Carbon Metabolism	130
IV. Nitrogen Metabolism	135
V. Hydrogen Metabolism	146

VI. Host-Microsymbiont Interactions	148
VII. Concluding Remarks	150
References	150

8. Oxygen Regulation and Hemoglobin

Warwick B. Silvester, Sharon L. Harris, and John D. Tjepkema

I. Introduction	157
II. Response of <i>Frankia</i> to Oxygen	158
III. Plant Growth and Nodule Development in Response to Varying Oxygen	161
IV. Internal Oxygen Environment in Nodules	164
V. Oxygen Effects on Nodule Function	166
VI. Hemoglobins in Actinorhizal Nodules	170
VII. Conclusions	173
References	174

9. Spore-Positive and Spore-Negative Nodules

Christa R. Schwintzer

I. Factors Determining Nodule Spore Type	178
II. Location of Spores within Nodules and Timing of Spore Development	180
III. Methods of Determining Nodule Spore Type	182
IV. Physiology of Sp ⁺ and Sp ⁻ Nodules	182
V. Ecological Distribution of Sp ⁺ and Sp ⁻ Nodules	185
References	191

10. The Molecular Genetics of *Frankia*

Beth C. Mullin and Chung Sun An

I. <i>Frankia</i> as an Actinomycete	196
II. <i>Frankia</i> as a Symbiont	203
III. Approaches to Studying <i>Frankia</i> Genetics	209
IV. Concluding Remarks	210
References	211

11. Micropropagation, Tissue Culture, and Genetic Transformation of Actinorhizal Plants and *Betula*

Armand Séguin and Maurice Lalonde

I. Vegetative Propagation	216
II. Genetic Transformation Systems for Betulaceae	226
III. Applications of <i>in Vitro</i> Techniques	231
References	233

12. The Genetics of Actinorhizal Betulaceae*Jean Bousquet and Maurice Lalonde*

I. Introduction	239
II. Diversity among Actinorhizal Plants	239
III. A Model Host Group for the Temperate Regions	242
IV. The Potential of Studies at the DNA Level	254
References	257

13. Techniques for Measuring Nitrogenase Activity in *Frankia* and Actinorhizal Plants*Lawrence J. Winship and John D. Tjepkema*

I. Nitrogen Balance	264
II. Isotope Enrichment	265
III. Isotope Dilution after ^{15}N Enrichment	265
IV. Natural Abundance Dilution	267
V. Acetylene Reduction	268
VI. Hydrogen Analysis	274
VII. Limitations and Problems Common to All Methods	275
VIII. Conclusions	277
References	277

**14. Methods for Production and Use of Actinorhizal Plants
in Forestry, Low Maintenance Landscapes, and
Revegetation***Larry F. Benoit and Alison M. Berry*

I. Considerations of Site Use and Planting Goals	281
II. Propagation of Actinorhizal Plants	282
III. Approaches to Establishing Actinorhizal Symbioses	289
IV. Outplanting and Follow-up	293
V. Conclusion	294
References	294

**15. Interactions among Actinorhizal and Associated Plant
Species***Jeffrey O. Dawson*

I. Complementary Interactions	299
II. Competitive Interactions	309
III. Conclusions	312
References	313

16. Current and Potential Uses and Management of Casuarinaceae in the Tropics and Subtropics*H. G. Diem and Y. R. Dommergues*

I. Introduction	317
II. Current and Potential Uses of Casuarinaceae	320
III. Root Symbioses in Casuarinaceae	324
IV. Plant Selection and Breeding for Increased N ₂ Fixation	333
V. Management Practices	334
References	338

17. Actinorhizal Plants in Pacific Northwest Forests*David E. Hibbs and Kermit Cromack, Jr.*

I. Introduction	343
II. Soil Building/Fertility	348
III. Use in Forest Production	350
IV. Utilization of Red Alder	354
V. Long-Term Productivity	356
VI. Nontimber Values	357
VII. Summary	358
References	358

18. Current and Potential Uses of Actinorhizal Plants in Europe*C. T. Wheeler and I. M. Miller*

I. Introduction	365
II. European Actinorhizal Species	367
III. Utilization for Land Management and Forestry	369
IV. Commercial Products	381
V. Future Prospects	384
References	385

Index

391