

# SOLUTE MOVEMENT IN THE RHIZOSPHERE

---

---

**P.B. TINKER, M.A., D.Sc.**

Senior Visiting Fellow  
Department of Plant Sciences  
Oxford University

**P.H. NYE, M.A., FRS**

Emeritus Reader in Soil Science  
Emeritus Fellow, St. Cross College  
Oxford University

New York      Oxford

Oxford University Press

2000

# Contents

---

Main Symbols xvii

## 1 Introduction 3

- 1.1 The Origin of Current Ideas 4
- 1.2 The Beginning of the Modern Period (*c.* 1940–1960) 5
- 1.3 Wider Perspectives 9
- 1.4 The Continuity Equation 11

## 2 Soil and Plant Water 14

- 2.1 Water Potential 14
- 2.2 Transfer of Water 20
- 2.3 Water Use by Plants 26
- 2.4 Conclusion 42

## 3 Solute Interchange between Solid, Liquid, and Gas Phases in the Soil 43

- 3.1 Composition of the Soil Solution 43
- 3.2 Buffer Power 51
- 3.3 Poorly Soluble Compounds 53
- 3.4 Cations with Multiple Valency 53
- 3.5 Adsorption of Anions 54
- 3.6 Rates of Ionic Interchange between Solid and Solution 57
- 3.7 Mineralization and Immobilization in Organic Forms 63

- 3.8 Applications to Whole Crop and Drainage Models 64
- 3.9 Sorption Reactions of Organic Materials 65

## 4 Local Movement of Solutes in Soil 71

- 4.1 Diffusion 71
- 4.2 Diffusion in Soils 77
- 4.3 Mass Flow and Dispersion in Solution 90
- 4.4 Gaseous Convection and Diffusion 93
- 4.5 Mechanical Movement 94

## 5 The Uptake Properties of the Root System 95

- 5.1 Root Morphology 95
- 5.2 The Ion Uptake Process 101
- 5.3 Ion Uptake Kinetics and Plant Demand 112
- 5.4 Plant Factors that Affect Uptake Rates 125
- 5.5 Environmental Variables that Affect Uptake Rate 128
- 5.6 Conclusion 129

## 6 Solute Transport in the Soil near Root Surfaces 130

- 6.1 Transport Processes 130

- 6.2 Experimental Evidence for Theory of Diffusion near Roots with Restricted Mass Flow 137
  - 6.3 Roots with Root Hairs 142
  - 6.4 Simultaneous Diffusion and Convection 145
  - 6.5 The Effect of Soil Moisture Level on Solute Absorption by Single Roots 150
  - 7 Chemical and Physical Modification of the Rhizosphere 156
    - 7.1 Physical Effects 156
    - 7.2 Chemical Effects 159
    - 7.3 Direct Effects of Soluble Exudates on Mineral Nutrition 172
  - 8 Microbiological Modification of the Rhizosphere 179
    - 8.1 Microbial Substrates in the Rhizosphere 179
    - 8.2 The Microbiological Community and the Processes of the Rhizosphere 185
    - 8.3 Effects on Plant Growth and Mineral Nutrition by Mycorrhizal Fungi 194
    - 8.4 Effects of Other Organisms on Nutrient Uptake and Growth 222
    - 8.5 Conclusion 223
  - 9 Root System Architecture, Density, and Measurement 224
    - 9.1 Root-Shoot Relations and the Allocation of Carbon into the Root System 224
    - 9.2 The Morphology and Measurement of Root Systems 230
    - 9.3 Factors Affecting Root Form and Distribution in Soil 241
    - 9.4 Root Distribution and Density in the Field 259
    - 9.5 The Modelling of Root System Growth and Morphology 263
  - 10 The Mineral Nutrition of Single Plants in Soil 269
    - 10.1 Types of Models 269
    - 10.2 Relationships between Nutrient Uptake, Plant Composition and Growth, and Soil Supply 272
    - 10.3 Root System Uptake Models for Simplified Conditions without Competition 283
    - 10.4 Uptake by Competing Roots within a Single Root System in Simplified Conditions 285
    - 10.5 Root System Uptake Models with Competition in Simplified Conditions 292
    - 10.6 Whole-Plant Growth and Uptake Models 303
    - 10.7 Conclusion 305
  - 11 Solute Transport and Crop Growth Models in the Field 308
    - 11.1 Uptake of Water and Nutrients by Field Crops in Relation to the Development of Crop Models 308
    - 11.2 Transfer of Solutes in a Profile 316
    - 11.3 Modelling of Monoculture Crops 330
    - 11.4 Nutrient Uptake by Mixed Vegetation 353
    - 11.5 Natural Vegetation 365
    - 11.6 Conclusion 370
- References 373
- Index 435