7. Function of Nutrients: Micronutrients

Martin Broadley, Patrick Brown, Ismail Cakmak, Zed Rengel and Fangjie Zhao

7.1 Iron	191
7.2 Manganese	200
7.3 Copper	206
7.4 Zinc	212
7.5 Nickel	223
7.6 Molybdenum	226
7.7 Boron	233
7.8 Chlorine	243

8. Beneficial Elements

Martin Broadley, Patrick Brown, Ismail Cakmak, Jian Feng Ma, Zed Rengel and Fangjie Zhao

8.1 Definition	249
8.2 Sodium	249
8.3 Silicon	257
8.4 Cobalt	261
8.5 Selenium	263
8.6 Aluminium	268
8.7 Other Elements	268

9. Nutrition and Quality

Franz Wiesler

9.1 Introduction	271
9.2 Nutrition and Appearance	272
9.3 Nutrition and Chemical Composition	273

10. Relationship between Nutrition, **Plant Diseases and Pests**

Don Huber, Volker Römheld and Markus Weinmann

10.1	General	283
10.2	Relationship between Susceptibility and	
	Nutritional Status of Plants	284
10.3	Fungal Diseases	285
10.4	Bacterial and Viral Diseases	291
10.5	Soil-borne Fungal and Bacterial Diseases	293
10.6	Pests	295
10.7	Direct and Indirect Effects of Fertilizer	
	Application on the Performance of	
	Plants and Their Parasites	297

11. Diagnosis of Deficiency and Toxicity of Nutrients	
Volker Römheld	
11.1 General	299
11.2 Nutrient Supply and Growth Response	299
11.3 Diagnosis of Nutritional Disorders by	
Visible Symptoms	300
11.4 Plant Analysis	301
11.5 Histochemical and Biochemical Methods	310
11.6 Plant Analysis versus Soil Analysis	311

Part II

Plant–Soil Relationships

12. Nutrient Availability in Soils

Petra Marschner and Zed Rengel

12.1 General	315
12.2 Chemical Soil Analysis	315
12.3 Movement of Nutrients to the Root	
Surface	316
12.4 Role of Root Density	324
12.5 Nutrient Availability and Distribution	
of Water in Soils	325
12.6 Role of Soil Structure	326
12.7 Intensity/Quantity Ratio, Plant Factors	
and Consequences for Soil Testing	328

13. Effect of Internal and External Factors on Root Growth and Development

Jonathan Lynch, Petra Marschner and Zed Rengel

13.1 General	331
13.2 Carbohydrate Supply	331
13.3 Root Development	332
13.4 Soil Chemical Factors	334
13.5 Soil Organisms	340
13.6 Soil Physical Factors	342
13.7 Shoot/Root Ratio	345

14. Rhizosphere Chemistry in Relation to Plant Nutrition

Günter Neumann, Volker Römheld

14.1 General	347
14.2 Spatial Extent of the Rhizosphere	349
14.3 Inorganic Elements in the Rhizosphere	350
14.4 Rhizosphere pH	353
14.5 Redox Potential and Reducing Processes	359
14.6 Rhizodeposition and Root Exudates	360

15. Rhizosphere Biology

Petra Marschner

15.1 General	369
15.2 Rhizosphere Microorganisms	369
15.3 Mycorrhiza	373

16. Nitrogen Fixation

Jim Cooper and Heinrich Scherer

16.1 General	389
16.2 Biological Nitrogen-fixing Systems	389
16.3 Biochemistry of Nitrogen Fixation	390
16.4 Symbiotic Systems	392
16.5 Amounts of N Fixed by Legumes, and its	
Transfer to Other Plants in Mixed	
Stands	405
16.6 Significance of Free-living and Associative	2
Nitrogen Fixation	407
16.7 Outlook	408

17. Adaptation of Plants to Adverse Chemical Soil Conditions

Eckhard George, Walter Horst and Elke Neumann

17.1 Natural Vegetation	409
17.2 High-input versus Low-input Approach	410

17.3 Acid Mineral Soils	417
17.4 Waterlogged and Flooded Soils	430
17.5 Calcareous and Alkaline Soils	444
17.6 Saline Soils	455

18. Nutrient and Carbon Fluxes in Terrestrial Agro-Ecosystems

Andreas Buerkert, Rainer Joergensen, Bernard Ludwig and Eva Schlecht

18.1 Microbiological Factors Determining	
Carbon and Nitrogen Emissions	473
18.2 Effects of Organic Soil Amendments on	
Emissions	475
18.3 Effects of pH, Soil Water Content and	
Temperature on Matter Turnover	475
18.4 Global Warming Effects	476
18.5 Plant-animal Interactions Affecting	
Nutrient Fluxes at Different Scales	476
18.6 Modelling Approaches in Matter Fluxes	482
S	

References	483
Index	645