



Water Dynamics in Plant Production

Wilfried Ehlers and Michael Goss



CABI Publishing

Contents

Preface	viii
Abbreviations	x
1 The Role of Water in Plant Life	1
1.1 Functions of Water in the Plant	1
Box 1.1: Light and water – prerequisites of photosynthesis	2
1.2 Adaptation Strategies of Plants to Overcome Water Shortage	3
1.3 Water and Net Primary Production	5
1.4 Water and Type of Vegetation	6
2 The Role of Water in Soil	10
2.1 Soil Genesis and Soil Functions	10
2.2 Soil Fauna and Vegetation Cover	12
3 The Interdependency of Soil Water and Vegetation	15
3.1 The Significance of the Soil for Water Storage	15
3.2 Transpiration and Seepage of Water with Different Types of Vegetation	16
4 Properties and Energy State of Water	20
4.1 Physical–Chemical Properties	20
4.2 The Concept of Water Potential and the Darcy Equation	22
5 Water Storage and Movement in Soil	26
5.1 Fundamentals and Principles	26
5.2 Evaporation	35
Box 5.1: Measuring soil water	35
5.3 Infiltration and Water Transport	43
Box 5.2: Preferential flow	47
6 The Root – the Plant's Organ for Water Uptake	49
6.1 The Role of the Root in the Plant	49
6.2 Structure of the Root Tip	51
Box 6.1: Methods of studying roots	52
6.3 Root Systems	56
7 The Water Balance of the Plant	64
7.1 Water Potentials in Plant Cells	64

7.2	Water Uptake by Roots	67
7.3	Transpiration by Leaves	71
	Box 7.1: Early experiments for determining water suction and water pressure of roots	72
7.4	The Action of Stomatal Guard Cells	76
7.5	Water Transport within the Plant	77
7.6	Water Potentials in Plants	80
	Box 7.2: Searching for the cause of sap ascent	82
8	The Plant as a Link between Soil and Atmosphere: an Overview	85
8.1	The Soil-Plant-Atmosphere Continuum (SPAC)	85
8.2	Potential Evapotranspiration	86
8.3	Relations between Potential Evapotranspiration, Soil Water and Transpiration	89
9	Water Use by Crops	95
9.1	Growth of Roots and Leaves	95
9.2	Leaf Area Index and Transpiration	95
9.3	Root System Development and Water Uptake	100
9.4	How Much of the Soil Water is Extractable by Plant Roots?	106
9.5	Stomatal Control of Water Vapour Loss	109
9.6	Water Use Throughout the Growing Season	110
9.7	How to Determine the Components of the Field Water Balance	113
9.8	Numerical Simulation	117
	Box 9.1: How lysimeters work	118
	Box 9.2: Measurement of water flow through plants	120
10	Radiation and Dry Matter Production	123
10.1	Radiation and Net Photosynthesis of Single Leaves	123
10.2	Radiation Interception and Dry Matter Accumulation in Crop Stands	125
11	Water Use and Dry Matter Production	132
11.1	Relations and their Optimization	132
11.2	The Transpiration Ratio and a Related Standard	135
	Box 11.1: The saturation deficit of the air determines transpiration efficiency	135
11.3	Water Use and an Estimate of Dry Matter Production	139
12	Influence of Nutrient Supply on Water Use and Establishment of Yield	141
12.1	Yield Dependency on Water and Nutrient Supply	141
12.2	Influence of Nutrient Supply on the Relationship between Water Use and Yield	144
12.3	Transpiration Efficiency and Fertilizer Application	149
13	Yield Formation under Inadequate Water Supply	153
13.1	Physiological Reactions and Assimilate Partitioning	153
13.2	Economic Yield	156
13.3	Water Shortage at Different Phenological Stages	159
14	Water Stress in Plants	165
14.1	Measuring Water Stress in Plants	165
14.2	How Plants Perceive Water Stress	171
	Box 14.1: Signalling between roots and shoots	174
15	Climatic Factors Influencing Yield	176
15.1	Growth-limiting Climatic Factors	176

15.2	Climate Change	184
15.3	Plants, Soils and Cropping Pattern in a Changing Environment	187
16	Breeding for Yield and Water Use	192
16.1	Comparing Old and New Cultivars	192
16.2	Future Strategies in Plant Breeding	196
17	Controlling the Soil's Water Balance by Soil Management	199
17.1	Which of the Balance Components can be Changed?	199
17.2	Controlling Infiltration	200
17.3	Controlling Evaporation	206
17.4	Increasing the Quantity of Extractable Soil Water	207
17.5	Conservation Tillage	210
18	Controlling Water Use by Crop Management	217
18.1	Crop Rotation	217
18.2	Choice of Species and Cultivars	224
18.3	Seeding and Stand Density	225
18.4	Fertilizer Application	230
19	Irrigation	234
19.1	Need, Concerns, Problems	234
19.2	Tapping Water – the Basis of Early Civilizations	236
19.3	Water Requirement of Crops	237
19.4	Timing and Adjusting the Application of Water	238
19.5	Efficient Water Use	240
19.6	Irrigation Methods	243
20	Epilogue	247
	References	248
	Index	263