

# MICROCLIMATE **The Biological Environment**

# Second Edition

## Norman J. Rosenberg

George Holmes Professor of Agricultural Meteorology and Director. Center for Agricultural Meteorology and Climatology, CAMaC

## **Blaine L. Blad**

Professor of Agricultural Meteorology, CAMaC

## Shashi B. Verma

Associate Professor of Agricultural Meteorology, CAMaC Institute of Agriculture and Natural Resources University of Nebraska-Lincoln

### **A Wiley-Interscience Publication**

## **JOHN WILEY & SONS**

New York · Chichester · Brisbane · Toronto ·

Singapore

# CONTENTS

List	of Sym	bols	xvii
Introduction			1
1	The Ra	diation Balance	5
	1.1	Review of Radiation Physics, 5	
	1.2	Solar Energy Receipts at the Surface of the Earth: Quantitative Effects, 10	N
	1.3	Solar Energy Receipts at the Surface of the Earth: Qualitative Effects, 33	
	1.4	Sky Radiation (Diffuse), 40	
	1.5	Shortwave Reflection (Albedo), 42	
	1.6	Thermal Radiation and Longwave Exchange, 49	
	1.7	The Net Radiation, 51	
	1.8	Relation of Net and Solar Radiation, 54	
	1.9	Earth's Radiation Balance, 57	
	1.10	Light Penetration into Plant Canopies and Water Bodies, 59	
	1.11	Instrumentation, 71	
		References, 83	
2	Soil He	eat Flux and Soil Temperature	94
	2.1	Introduction, 94	
	2.2	Laws of Heat Conduction and Thermal Properties of Soils, 94	
	2.3	Penetration of Heat into the Ground, 99	
	2.4	Daily and Seasonal Patterns of Soil Temperature, 99	
	2.5	Soil Temperature Profiles, 101	
	2.6	Texture Influences on Soil Heat Flux and Temperature, 103	
	2.7	Soil Heat Flux and Water Relations in Soils, 107	
	2.8	Soil Heat and Soil Respiration, 111	

#### xii CONTENTS

2.9 Instrumentation, 112 References, 115

## 3 Air Temperature and Sensible Heat Transfer

- 3.1 Introduction, 117
- 3.2 Adiabatic Process, Potential Temperature, 117
- 3.3 The Concept of Thermal Stability, 118
- 3.4 The Wet Adiabatic Lapse Rate, 119
- 3.5 Temperature Profiles above Natural Surfaces, 121
- 3.6 Sensible Heat Transfer in the Atmospheric Surface Layer, 123
- 3.7 Resistance Approach for Estimating Sensible Heat Flux, 123
- 3.8 Temperature Profiles in Plant Canopies, 126
- 3.9 Daily and Annual Temperature Patterns, 126
- 3.10 Influence of Elevation on Air Temperature Patterns, 129
- 3.11 Instrumentation for Air Temperature Measurement, 130 References, 132

## 4 Wind and Turbulent Transfer

- 4.1 Air Flow over a Rigid Surface: Some Definitions and Concepts, 134
- 4.2 Wind Speed Profile and Momentum Exchange, 135
- 4.3 Internal Boundary Layer and Fetch Requirements, 139
- 4.4 Atmospheric Stability, 140
- 4.5 Flux Profile Relationships, 142
- 4.6 Eddy Correlation Technique for Estimating Energy and Mass Fluxes, 144
- 4.7 Wind Speed within Crop Canopies, 146
- 4.8 Daily Wind Patterns, 147
- 4.9 Seasonal Patterns of Wind Direction and Speed, 148
- 4.10 Wind Speed Instrumentation, 154 References, 164

### 5 Atmospheric Humidity and Dew

- 5.1 Introduction, 167
- 5.2 Physical Review, 168
- 5.3 Measures of Humidity, 169

134

- 5.4 The Concept of Saturation, 170
- 5.5 Saturation-Based Measures of Humidity, 171
- 5.6 Humidity Structure of Air, 172
- 5.7 Profiles of Vapor Pressure, 174
- 5.8 Dew, 175
- 5.9 Instrumentation for Humidity Measurement, 178
- 5.10 Instruments for Measurement of Dew, 187 References, 187

## 6 Modification of the Soil Temperature and Moisture Regimes

190

209

- 6.1 Introduction, 190
- 6.2 Slope and Aspect, 191
- 6.3 Mulching, 195
- 6.4 Artificial Heating of the Soil, 201 References, 206

## 7 Evaporation and Evapotranspiration

- 7.1 Introduction, 209
- 7.2 Importance of Evaporation and Transpiration, 212
- 7.3 Soil, Plant, and Climatic Influences on Evapotranspiration, 217
- 7.4 Soil–Plant–Atmosphere Continuum, 239
- 7.5 Estimation of Evaporation and Evapotranspiration, 241
- 7.6 Measurement of Evapotranspiration, 258
- 7.7 Separation of Evaporation and Transpiration, 265
- 7.8 Application of Evapotranspiration Methods to Special Situations, 267
  References, 271

#### 8 Field Photosynthesis, Respiration, and the Carbon Balance

- 8.1 Introduction and Definitions, 288
- 8.2 Gross and Apparent Photosynthesis, 291
- 8.3 Photosynthesis as a Resistance Process, 292
- 8.4 Environmental Factors Affecting Photosynthesis, 293
- 8.5 Environmental Influences on Respiration, 299
- 8.6 Carbon Balance in the Field, 302
- 8.7 Radiant Energy Conversion in Photosynthesis, 308
- 8.8 Water Use Efficiency, 312
- 8.9 Measurement of Photosynthesis in the Field, 318

### xiv CONTENTS

8.10 Measuring the Respiration Components, 324 References, 326

## 9 Windbreaks and Shelter Effects

- 9.1 Introduction, 331
- 9.2 Interrelations of Wind Shelter, Moisture Conservation, Plant Growth, and Yield, 334
- 9.3 Wind Speed and Turbulence in Shelter, 336
- 9.4 Microclimate in Shelter, 341
- 9.5 Plant Physiological Responses to Shelter, 350
- 9.6 Potential and Actual Water Use, 352
- 9.7 The Effect of Shelter on Photosynthesis, 359
- 9.8 The Effect of Shelter on Water Use Efficiency, 360
- 9.9 Some Integrative Schemes of the Spatial Differences in Shelter Effects, 361 References, 363
- **10** Frost and Frost Control
  - 10.1 Introduction, 368
  - 10.2 Types of Frost, 371
  - 10.3 The Climatology of Frost Incidence, 373
  - 10.4 Methods of Frost Protection, 375 References, 388

#### 11 Water Use Efficiency in Crop Production: New Approaches

- 11.1 Introduction, 391
- 11.2 Antitranspirants, 392
- 11.3 Reflectants, 396
- 11.4 Plant Architecture, 404
- 11.5 Carbon Dioxide Enrichment, 409 References, 419

## 12 Human and Animal Biometeorology

- 12.1 Introduction, 425
- 12.2 Radiation Balance, 427
- 12.3 Energy Balance, 433
- 12.4 The Climate Space, 446

# 331

368

391

- 12.5 Effects of Climate on Humans, 449
- 12.6 Effects of Climate on Animals, 460
- 12.7 Adaptation and Acclimatization, 462 References, 463

## **Author Index**

Subject Index

481