16 Modelling of Photosynthetic Response to Environmental Conditions

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Contents

16.1 Introduction 550

16.2 Stromal and Extrachloroplastic Reactions 551
  16.2.1 Kinetics of Ribulose Bisphosphate Carboxylase-Oxygenase 551
    16.2.1.1 RuP₂ Saturated Rates 551
    16.2.1.2 RuP₂ Limited Rates 552
    16.2.1.3 On the High Concentration of Enzyme Sites 553
    16.2.1.4 Activation of RuP₂ Carboxylase-Oxygenase 554
    16.2.1.5 “Enzyme-Associated” Rate of CO₂ Assimilation 555
  16.2.2 “Day” Respiration 555
  16.2.3 CO₂ Compensation Point, R 556
    16.2.3.1 Introduction 556
    16.2.3.2 Rₜ ≥ Eₜ, Rₜ = 0 556
    16.2.3.3 Rₜ ≥ Eₜ, Rₜ > 0 557
    16.2.3.4 Rₜ < Eₜ, Rₜ = 0 558
    16.2.3.5 Rₜ < Eₜ, Rₜ > 0 558
  16.2.4 Regeneration of RuP₂ — Stromal and Extrachloroplastic Reactions 558
    16.2.4.1 Introduction 558
    16.2.4.2 Photorespiratory Carbon Oxidation Cycle 558
    16.2.4.3 PGA Production, ATP and NADPH Consumption in the Integrated PCR and PCO Cycles 559
    16.2.4.4 Enzymatic Steps from PGA to RuP₂ 560

16.3 Thylakoid Reactions 562
  16.3.1 Introduction 562
  16.3.2 Temperature Dependence of Potential Electron Transport Rate 563
  16.3.3 NADPH Production 563
  16.3.4 ATP Production 564
    16.3.4.1 Introduction 564
    16.3.4.2 Non-Cyclic Photophosphorylation via Whole-Chain Electron Transport 565
    16.3.4.3 Pseudo-Cyclic Electron Transport (Mehler Reaction) 566
    16.3.4.4 Cyclic Photophosphorylation 566
    16.3.4.5 DHAP/PGA Shuttle 567
    16.3.4.6 Photosynthetic Control of Whole-Chain Electron Transport 567

16.4 Integration of Factors Limiting RuP₂ Regeneration 568

16.5 Integrated C₃ Metabolism 569
  16.5.1 Rate of CO₂ Assimilation, A 569
  16.5.2 Quantum Yield 571
  16.5.3 Carboxylation Efficiency 573
    16.5.3.1 Introduction 573
16.1 Introduction

Photosynthesis is the incorporation of carbon, nitrogen, sulphur and other substances into plant tissue using light energy from the sun. Most of this energy is used for the reduction of carbon dioxide and, consequently, there is a large body of biochemical and biophysical information about photosynthetic carbon assimilation. In an ecophysiological context, we believe that most of today's biochemical knowledge can be summarized in a few simple equations. These equations represent the rate of ribulose bisphosphate (RuP₂)-saturated carboxylation, the ratio of photorespiration to carboxylation, and the rates of electron transport/photophosphorylation and of “dark” respiration in the light. There are many other processes that could potentially limit CO₂ assimilation, but probably do so rarely in practice. Fundamentally this may be due to the expense, in terms of invested nitrogen, of the carboxylase and of thylakoid functioning. To reach our final simple equations we must first discuss the biochemical and biophysical structures — as they are understood at present — that finally reduce the vast number of potentially rate-limiting processes to the four or five listed above. A diagrammatic representation of these processes is given in Fig. 16.1.

We then discuss integrated functioning in individual leaves of C₃ species, and later briefly discuss canopy photosynthesis. Models of C₄ photosynthesis are less well developed than those of C₃ photosynthesis; we discuss how they may be extended. (For description of these pathways of photosynthesis see also Chap. 15, this Vol.)

Models of leaf photosynthesis have been reviewed by THORNLEY (1976), JASSBY and PLATT (1976), and TENHUNEN et al. (1980a). In this article we emphasize recent progress made in mechanistic models, but recognize the validity of other types (see Chap. 8, this Vol.) and give brief references to successful empirical models. Stomatal and boundary layer conductances affect the intercellular partial pressure of CO₂, C, and the leaf temperature, T. We examine responses of the rate of assimilation to C and T but do not consider submodels