aid workers aiming to improve food security, protect the environment, and alleviate poverty in rural Africa, particularly in marginal environments which urgently need sustainable and profitable cropping systems. Indeed sustainable crop and natural resource management coupled with new, resilient, improved cultivars and their healthy propagules, which may possess traits for agro-processing and commerce, is critical for enhancing the livelihoods of the rural poor in Africa through access to local, regional, and international markets.

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**Redesigning Rice Photosynthesis to Increase Yield.** Edited by J.E. SHEEHY, P.L. MITCHELL, and B. HARDY. Elsevier Science B.V., Sara Burgerhartstraat 25, P.O. Box 211, 1000 AE Amsterdam, the Netherlands. 2000, Hardcover, 300 pp., $149.00. ISBN 0-444-50610-1.

This text contains the proceedings of the “Workshop on the Quest to Reduce Hunger: Redesigning Rice Photosynthesis,” sponsored by the International Rice Research Institute (IRRI) in 1999. IRRI estimates that a 50% increase in rice yield is needed by 2050 to keep pace with the world’s population growth. Yet, the yield of bred rice cultivars appears to have reached a maximum. The purpose of the IRRI workshop was to examine the feasibility of redesigning rice photosynthesis to overcome current yield limits.

There are several major types of land plants based on differences in their mechanism of CO₂ assimilation. In C₃ plants, such as rice, Rubisco fixes CO₂ into a C₃ compound (phosphoglycerate) by the carboxylation of ribulose bisphosphate (RuBP). This reaction is inhibited by atmospheric O₂, which competes with CO₂ at the Rubisco active site. Oxygen fixed in this way wastes energy via the process of photorespiration. C₄ plants have succeeded in eliminating photorespiration by splitting the reactions of photosynthesis between two types of cells, mesophyll cells (MC) and bundle sheath cells (BSC) (Kranz anatomy). In the C₄ pathway, CO₂ is initially fixed by PEPC (phosphoenolpyruvate carboxylase) in the MC to form oxaloacetate, a C₄ compound. The oxaloacetate is subsequently converted to malate, which diffuses into the BSC, where it is decarboxylated to form CO₂ and pyruvate. The CO₂ is refixed by Rubisco in the Calvin Cycle, as in C₃ plants, whereas pyruvate diffuses back to the MC to be converted to PEP by PPDK (pyruvate, orthophosphate dikinase), thus completing the C₄ cycle.

Because C₃ plants, such as maize, are capable of concentrating CO₂ at the Rubisco active site, they have many desirable agronomic traits, including high photosynthetic capacity and high mineral-use efficiency, especially under high light, high temperature, and drought conditions. The C₄ species, on the other hand, have lower photosynthetic efficiencies because of the O₂ inhibition of photosynthesis and the associated photorespiration. A central theme in this book is whether yield can be improved by generating a rice plant with C₄ photosynthesis. Because conventional hybridization efforts toward this goal have been unsuccessful, the text emphasizes the efficacy of various genetic engineering approaches to address this question.

**Perspectives** (two chapters) explores, first, the economic impact of yield improvements in rice on the alleviation of global poverty, and second, the eco-physiology of C₃ and C₄ plants, with an emphasis on their expected performance under elevated atmospheric CO₂ conditions (global climate change). The four chapters of the next section, **Models, Structure, and Growth,** raise themes that are discussed throughout the text. These include the processes by which solar energy is converted into grain; the factors that determine the maximum yield limit of C₃ rice; the factors that might define the yield limits of rice with redesigned C₄ photosynthetic pathways; and problems associated with engineering a C₄ rice (e.g., difficulties in generating a rice plant with a Kranz anatomy). Given that C₄ but not C₃ photosynthesis will be enhanced by future conditions of elevated atmospheric CO₂, this section also presents an alternate strategy to improve C₃ photosynthesis itself that involves the manipulation of sucrose phosphate synthase (SPS) activity.

The next section of the book, **C₃ and C₄, Pathways** (four chapters), focuses on the structural and metabolic features of CO₂-concentrating mechanisms in plants, algae, and cyanobacteria. Prominent topics include the overcycling of the C₄ pathway, the energetics of photorespiration, CO₂ diffusion resistance between Rubisco and PEPC, and metabolic cross-talk between the BSC and MC. Limitations in C₃ photosynthesis are discussed from the standpoint of leaf developmental factors and photoacclimatory responses, and a “scaling up” approach is used to identify limitations at the cellular level, in photorespiration and in canopy performance. Conditions under which rice might benefit from a CO₂-concentrating mechanism are also considered. For instance, improvements in the capacity to convert triose phosphates to starch and sucrose might enhance productivity under conditions of low temperature and high light. The **Genes, Physiology and Function** section (3 chapters) describes attempts to transform rice with a primitive C₃ metabolism, similar to that found in the aquatic macrophyte *Hydrilla,* which lacks a Kranz anatomy. The generation of transgenic rice with high level expression of PEPC and PPDK are also described. These plants apparently have enhanced photosynthetic capacity and yield. This section concludes with an examination of rice productivity from the standpoint of the carbon–nitrogen balance of the plant, including shoot-root interactions and interactions between carbon and nitrogen metabolism. Echoing conclusions of earlier chapters, SPS and PEPC were identified as potential targets of regulation.

The **Practical Issues** section (four chapters) reviews strategies for developing rice varieties with increased yield potential, including population improvement, ideotype breeding, heterosis breeding, genetic engineering and molecular breeding. It is argued that increases in yield will come from improvements in single-leaf versus net canopy photosynthesis, and implications of these improvements on mineral-nutrition are discussed. The last chapter of this section examines intensive irrigated rice systems and future challenges to crop management. A final **Reflections** section (two chapters) deals with the potential benefits and risks of genetically modified (GM) crops, and concludes with an excellent summary of the text. The summary focuses on a list of nearly 30 research recommendations culled from the 19 chapters that might be undertaken to improve rice photosynthesis and that might have a fundamental impact on yield potential.

I was favorably impressed with *Redesigning Rice Photosynthesis to Increase Yield.* The chapters were written by a distinguished group of scientists who represent diverse areas of photosynthesis research. Succinct, informative abstracts prefaced each chapter, and the chapters themselves were uni-