Genetic Improvement of Bioenergy Crops

Wilfred Vermerris
Editor

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Preface

Bioenergy is receiving increasing attention in science, politics, industry and the media. As a result, bioenergy is no longer an obscure topic pursued by ideologists striving for a green economy in which everyday luxuries have to be sacrificed. Instead, the bioeconomy is touted as a new economic model that offers green growth, i.e. economic opportunities that rely on sustainable, environmentally-friendly production and consumption.

Several factors have contributed to this change. Global climate change, once a hotly debated topic, appears to have become accepted as a real phenomenon with potentially catastrophic consequences for both the environment and the global economy. The change in perception of global climate change is the result of intense research and effective communication of that research by many people, including the 2007 Nobel Peace Prize laureates, the United Nations International Panel on Climate Change (IPCC) and former United States vice-president Al Gore. Other developments that have contributed to this awareness include the devastating impact of hurricane Katrina in 2005, massive forest fires in the western and southeastern United States due to prolonged drought, and the realization that weather patterns in many parts of the world in the recent years seem more erratic. In addition, crude oil prices, which have been stable for decades between US\$25 and \$35 per barrel, are now closer to US\$80 per barrel, and on January 4, 2008 hit the much-dreaded price of US\$100 per barrel. This increase in the oil price is indicative of the fact that oil reserves are finite, while global demand for oil will continue to rise. Given that oil is used on a global scale but that oil production is controlled by a limited number of countries, individual countries have very little influence of oil prices.

This book was written with the belief that energy production and use based on the 'business-as-usual' model are not sustainable in the future, due to the impact on the climate, the growing world population, and the fact that oil reserves are finite. Bioenergy is not a magic solution to the world's energy needs, but it has the potential to contribute significantly to these needs, when used in combination with conservation programs and other sources of alternative energy.

In order for bioenergy to become a reality, a lot of elements need to be put in place. This includes the infrastructure to harvest, transport and process biological materials, the infrastructure to distribute the fuels and green chemical feedstocks produced from these materials, and the vehicles and down-stream processes that use the bioenergy. At the base of this bioenergy production chain are the plant feedstocks. At the time of this writing, the two main sources of bioenergy are corn starch in the United States and sugar from sugar cane in Brazil. Given the anticipated increase in the demand for bioenergy, and the concern that food and feed security are at risk if corn starch and sugar continue to be the main feedstocks, the consensus is that lignocellulosic biomass is a better feedstock for the long term. At this time, the technology to produce fuels from these feedstocks is not mature, and the feedstocks themselves have not been developed for bioenergy production *per se*. Bioenergy production can therefore become much more efficient if both the feedstocks and the processing technology are optimized. The main focus of this book is on the genetic strategies that are available for improving bioenergy crops that can be used for the production of ethanol and other chemical derived from lignocellulosic biomass.

This book is divided into two parts. Part I provides background information on bioenergy production and includes a description of the current practice for ethanol production from grain, what the processing options are when lignocellulosic biomass is used, what lignocellulosic biomass is and how it is synthesized in the plant, and how you can chemically characterize and evaluate biomass. Part I also contains a primer on plant breeding and genetics for those readers that are unfamiliar with these topics. Part II provides an overview of a number of important bioenergy crops. Each chapter covers one crop or a group of related crops, and describes the biology, crop use and crop potential, genetic strategies and plant breeding efforts as they relate to bioenergy production. The focus of this book is on so-called biomass crops, where carbohydrates provide the main source of energy. This can be either in the form of sugar used directly in microbial fermentation or in form of cell wall polysaccharides that are processed to fermentable sugars or that are used in thermo-chemical processing (syngas, co-firing). Oil crops for the production of bio-diesel are not covered in this book, largely because the chemistry and processing are very different, and this would likely have resulted in a lack of focus. While bioenergy is of global interest, many of the chapters have a focus on production in the United States. This is the result of several recent initiatives in this country that have led to a stimulus of research on genetic improvement and bioprocessing and that have also resulted in the construction of many new processing plants. The selection of crops represented in Part II is based on the potential for large-scale bioenergy production, and on the presence of active crop improvement programs with a focus on bioenergy. Obviously, some crops not represented in this book may become suitable bioenergy crops in the future, especially after several years of research and breeding.

The book is designed for use as a textbook for a course on bioenergy production at the graduate student level. At the University of Florida this book is used for a course with the same name as the book, offered through the department of Agronomy, and open to students from other departments in the plant sciences, as well as students in chemical and biological engineering with an interest in learning

more about feedstock composition and modification. This three-credit course covers more or less one chapter per week, and is supplemented with articles from the primary literature. While this book is written as a text book, it will also be of interest for researchers at academic institutions, government research facilities, and private industry as well as for policy makers in the bioenergy area.

As the editor of this book, I would like to thank the chapter authors for their valuable contributions, Randi Wheeler for her assistance with the editing and reference formatting, Miguel Castillo and Nesbit Tyler for proofreading chapters, and Jinnie Kim and Jillian Slight at Springer for their encouragement and flexibility. This book would not have been possible without the support at home from Lauren and Deirdre. I am grateful for their patience, especially when the writing took place on evenings and in weekends. This book is dedicated to my (currently) 7-year old daughter Deirdre, as a representative of the next generation that will have to face the consequences of the energy-related and environmental choices the current generation makes.

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Spring 2008

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