Antonio Costa de Oliveira · Rajeev K. Varshney *Editors*

Root Genomics

With the predicted increase of the human population and the subsequent need for larger food supplies, root health in crop plants could play a major role in providing sustainable highly productive crops that can cope with global climate changes. While the essentiality of roots and their relation to plant performance is broadly recognized, less is known about their role in plant growth and development.

Root Genomics examines how various new genomic technologies are rapidly being applied to the study of roots, including high-throughput sequencing and genotyping, TILLING, transcription factor analysis, comparative genomics, gene discovery and transcriptional profiling, post-transcriptional events regulating microRNAs, proteome profiling and the use of molecular markers such as SSRs, DArTs, and SNPs for QTL analyses and the identification of superior genes/alleles. The book also covers topics such as the molecular breeding of crops in problematic soils and the responses of roots to a variety of stresses.

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Foreword

Root Biology: An Inconvenient Truth

The truth is that roots usually are as extensively underground as the aerial portions are above the ground. Crop plants would not live without roots. Roots absorb water and nutrients and anchor the plant in the soil. So why do not we know more about roots? It is likely due to the inconvenience of phenotyping root characteristics – and many of today's phenotyping methods are destructive. While we recognize the essentiality of roots and their relation to plant performance, the scientific community has not placed a sufficiently high priority on their analysis to make the needed major advances. Many of the factors that affect root health can result in a 50% yield loss when deficient. Given that the predicted human population increase is 50% by 2050, the improvement of root health in crop plants could play a major role in meeting the world's need for increased food.

The study of root biology involves extensive plant–soil–water interactions that are complicated by the microorganisms and insects in the rhizosphere that can alter root development. Each of the possible interactions has feedback effects in the plant; many effects are long-range effects within the plant. The soil environment relates to nutrient availability and uptake, which reflects the condition of the soil including acidity. Even alternation of dry and flooded conditions changes various ion states, which can change with the duration of flooding. Many climate change scenarios predict water shortages, making the understanding of root biology even more important in the future.

Much of today's phenotyping of roots is based on root architecture, such as root length, root diameter, root proliferation, root biomass, root mass density at different soil depths, diameter, and distribution of meta-xylem vessels, and root-to-shoot ratios. Early maturity, early shoot-growth vigor, and depth and rapidity of water absorption also are often assessed among other factors. New nondestructive approaches need to be encouraged such as X-ray imaging, light transmission imaging, and time-lapse recordings of root growth.

This book clearly documents that many new genetic/genomic technologies are rapidly being applied to the study of roots, including high-throughput genome sequencing, TILLING, use of molecular markers such as SSRs, DArTs, and SNPs for introgression of favorable genes, QTL analyses, marker assisted breeding, gene discovery, comparative mapping, transcription factor identification, transcriptional profiling, posttranscriptional events regulating microRNAs, and proteome profiling with complete roots. Some genetic approaches are constrained – such as genome-wide selection and gene cloning – by the difficulty in phenotyping.

Plants coordinate root growth with the soil environment. Many factors can inhibit root growth. In this book, aluminum, iron, and salt toxicity are extensively reviewed, providing a great deal of useful information. The root system is the primary site of interaction with the soil environment, which includes exudates of organic compounds from the plants and the microbes. Some of these exudates are known to represent signals that regulate microbe behaviors and even germination of seeds.

As illustrated in this book, it is amazing what we know about roots and their importance, but equally amazing is what we do not know – and we know even less about the complicated interactions and feedback mechanisms. The work reviewed in this book also shows the value of using model species such as *Arabidopsis*; e.g., 22 genes have been reported in *Arabidopsis* on lateral root development, 19 genes on primary root development, and 8 genes on root-hair formation.

One of the goals of this book was to show how root research relates to sustainable crop productivity. The chapters taken together represent an extensive review of the topic focusing primarily on highly productive crops under rainfed conditions. Crops are mostly rainfed in the most populated areas of the world; this suggests that it is imperative that root biology be a major research emphasis in the coming years – but will that be the case? Will the "inconvenient truth" be recognized?

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Preface

With the emerging recognition that agriculture needs to approach sustainability, the plant–soil–water interactions become of paramount importance in crop systems. In this scenario, roots arise from a minor to a major role in the understanding of plant growth and development. Novel technologies allow us to scan genomes in the fastest way ever, and there is not a day without further developments leading to cheaper and more precise genotyping techniques. However, the complexity of underground metabolism and the responses of root systems to a variety of stresses call for improvements in phenotyping as well as genotyping techniques.

The idea of organizing a book on Root Genomics dates as back as early 1990s in the graduate benches of Purdue University. The fascination with a system so important for the plant but yet so unknown served as both an incentive and a challenge to pursue this line of research. In 2002, an important opening for root biology occurred when the late Dr. Mike Gale, *FRS*, agreed to include a workshop in Root Genomics at the Plant and Animal Genome Meetings, held yearly at San Diego, CA. Since 2003, this workshop has generated fruitful discussions and created new paths for root research. Many speakers from different countries shared their experience in root genomics, regardless if they were working with model or crop species. One of the speakers, Rajeev Varshney, was very impressive in his enthusiasm and determination to target important aspects of drought stress. Sharing the same enthusiasm for studying roots and stress responses was crucial to put the idea of this book forward. Many of the authors have presented their work in the Root Genomics Workshop, but all were chosen by their significant contributions to agricultural and plant sciences and their common efforts for a better world. We are grateful to all the authors who not only provided a timely review of the published research work in their area of expertise but also shared their unpublished results to offer an updated view. We also appreciate their cooperation in meeting the deadlines, revising the manuscripts and in checking the galley-proofs.

We are thankful to Dr Jeff L. Bennetzen, who as a brilliant geneticist was a great role model and a friend (ACO) that has indirectly inspired this line of research. We thank Dr. Ronald Phillips, a major pioneer in the field of plant genetics and

genomics and the father of many ideas that influenced modern plant sciences, for writing the foreword.

Both of us also recognize that the editorial work for this book took away precious time that we should have spent with our respective families. ACO acknowledges the efforts of his parents, Glauco and Izabel, for providing an atmosphere of learning and investigative thought during his young years, his wife Carla for her continuous encouragement, patience, and friendship, and his children Victoria (Vickie) and Eduardo (Dudu). Similarly, RKV acknowledges the help and support of his wife Monika and his children Prakhar (Kutkut) and Preksha (Nanu) who allowed their time to be taken away to fulfill RKV's editorial responsibilities in addition to research, managerial, and other administrative duties at ICRISAT and Generation Challenge Programme (GCP).

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