Guttation

Guttation is the phenomenon of bleeding or oozing of exudates or fluids from plant organs through special structures called hydathodes or sometimes 'water stomata' or 'water pores', located on the tip, periphery, and surfaces of leaves. This text is an up-to-date review of the knowledge in the field and it discusses the principles, mechanisms, regulation, and applications of guttation. The book covers genetic, environmental, and edaphic factors that control and regulate the phenomenon of guttation. It comprehensively discusses the impact of guttation on important aspects including soil–plant–animal–environment systems, soil fertility and soil productivity, plant water balance, plant physiological research, ecosystem maintenance, and hydathode retrieval of water and solute. A separate chapter covers the applications of guttation in the production of recombinant proteins for commercial use, seed protein, alkaloids, pharmaceutical drugs, resins, gums, and rubber.

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Guttation

Fundamentals and Applications

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*To the loving memory of my mother, Mrs Sampatti Devi,
who left for her heavenly abode on November 30, 2017 (1950–2017),
who has been a rock of stability throughout my life, and whose
loving spirit sustains me still. May her soul rest in peace.*

Contents

Figures

Tables

Foreword

Guttation is a prominent example of natural secretion, containing organic and inorganic solutes, by plant leaves. The oldest references related to guttation in this volume are the studies of de Saussure (1804) followed by the studies of Duchartre (1859) and Unger (1861) on the secretions of calcareous matters and other compounds and salts of leaves. The author of the book, Sanjay Singh, from the windows of his parents' house saw guttation with its myriad brilliant drops glistering on the tips of leaves of rice plants in the early morning sunshine. He fell in love with guttation in his childhood. He followed it up throughout his professional academic life as a teacher, a researcher, and an author of a number of review articles. The present book is born out of this love.

The book is unique because until now no such treatise on guttation existed. It takes the important phenomenon of guttation out of unjustified relative negligence. The book is a comprehensive source of references on guttation with a remarkable completeness in coverage of the literature. Beyond that, the author provides far-reaching excursions into the background of how guttation and related phenomena such as root exudation are embedded in general in the various fascinating features of plant life including water relations and transport, solute transport, regulation in response to external and internal signals, and ecology. From this, it unfolds guttation as innovative emergence in the true sense of the term. Doing this, the author with over 600 references covers an immense breadth of the literature going back to the beginning of the 19th century and up to the most recent works on implications of molecular biology. Through this monumental work, the author has created a history on guttation research, which forays into many outlooks on further work and progress to be anticipated.

With techniques of sampling and quantification of guttation, inorganic and organic chemistry of guttation, biotic interactions with viruses, bacteria, fungi, and animals, and with pharmaceutical implications, the various chapters of the book, which can be taken as self-contained entities, evidently address a very broad audience interested in plant biology, ecology, agriculture, horticulture, animal husbandry, pharmacology, and medicine. Thus, the book is worth being kept on personal bookshelves by students, teachers, and researchers and being acquired by private and government institutions interested in policy advice, libraries of colleges, and universities for use in teaching and research. Repeatedly, in the book, the author's sincere concern shines up striving to promote the understanding of guttation for serving human advantage in innovative supply and sustainable management of resources.

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Preface

The childhood perception of multiple observations of a visible plant event turning into an academic pursuit has been a miraculous twist in my life, which made all the difference between what I am today and what I might have been in the past. The early morning sunlight reflected by diamond-like water drops oozing profusely from rice plants growing all around my house, officially provided to my father, Professor Tarak Nath Singh, by Narendra Deva University of Agriculture & Technology Crop Research Centre, Faizabad in India where I was born, raised, and educated, triggered my mind during school days and aroused curiosity and anxiety regarding this fascinating and intriguing phenomenon of plant oozing, that is, guttation. Driven by the desire to understand guttation, I had then decided to work on these so-called teardrops of plants to unravel the internals and externals of how, when, why, and what spectra of this phenomenon, setting aside the prospect of choosing medical or engineering streams of education for lucrative job opportunities. The curiosity that was aroused during my school days culminated in investigations on guttation, constituting a chapter on it in my doctoral thesis submitted to Dr R. M. L. Avadh University, Faizabad, UP, India. With this began the exploratory journey on guttation that has seen no end till date, resulting in several invited publications on this subject authored by me. My guttation journey was further boosted by organizing and hosting the 'First World Congress on Guttation and Root Pressure' from December 2, 2015 to December 5, 2015 at the College of Agriculture & Rural Transformation of the University of Gondar, Ethiopia, which was attended by overseas guttation specialists from the United States, Germany, the Netherlands, Israel, and Hong Kong, in addition to those from within Ethopia. As a matter of fact, guttation has never been in the mainstream of research because of the prevalent belief and opinion that it is of no use to plants and people, which, of course, was proved wrong as you will witness when you harbor through different chapters of this book. It is this wrong notion that actually stirred and teased me so much that I began digging the literature on this topic from the beginning of this millennium and accumulated a good amount of information, old and new, on different aspects of guttation since its discovery in 1672 by Abraham Munting about three-and-a half-centuries ago (to be exact 348 years) in the Netherlands (erstwhile Holland). However, it is by no means an exhaustive collection, and I may kindly be excused for having inadvertently missed referencing the contributions of some authors. Subsequent to preliminary topic-wise classification and synthesis, the idea crystallized for writing a book. So, the book, first and only one ever written on guttation, is in your hands.

For the sake of clarity and maintaining the sequence of various aspects of guttation in order as far as possible, this book has been organized into 9 chapters. Chapter 1 deals with the nature of guttation, its machinery, and the biography of its discoverer. Chapter 2 describes the principles of guttation and its quantification, whereas Chapter 3 details the mode and mechanism of guttation, reflecting on the chain of events involved in this process. Chapter 4 reflects on the genetic, environmental, and edaphic factors that regulate the phenomenon of guttation. Going further, Chapter 5 gives readers a glimpse of its chemistry—both organic and inorganic aspects. Chapter 6, not behind its predecessor chapters in substance and material, goes on to presenting pathological aspects, pathogenic and non-pathogenic, including phycology, mycology, bacteriology, and virology of guttation. Matters of most significant interest to readers and scholars that now stand to dispute and set aside the previous negative belief and opinion about guttation have been highlighted in Chapter 7, which deals with its impact on soil–plant–animal–environment systems including biomass formation, agriculture, horticulture, forestry, soil, water, animal, ecosystem balance, etc. Chapter 8 sheds light on the latest discovery of secretion of biopharmaceuticals, paving the path for cheaper, safer, and faster production of drugs, vaccines, and a number of recombinant proteins by molecular farming for guttation and rhizosecretion, for animal and human well-being under changing environment and society. Finally, Chapter 9 draws integrated conclusions, apart from those indicated at various places in previous chapters as and when required, and underlines the future perspectives, pointing out gaps in our knowledge of guttation, which is expected to ignite the minds of students, teachers, and scholars to take up research into this so far least talked and written-about topic in plant biology with the objective of translating it into a subject to be extensively researched to explore the unresolved issues of guttation and root secretion to the advantage of mankind, as the biology of guttation is connected to our lives in many ways.

Here, I would like to mention that the computer typing of the manuscript, draft after draft, was done by me alone, depriving my daughter Yashvi, son Reyansh, wife Sangita, and my respected mother late Mrs Sampatti Devi of my due love, affection, and care for them, taxing heavily on their social and family life. I highly appreciate their limitless patience during the write-up up to the final submission of the manuscript of the book after its various chapters had been reviewed by learned specialists of the world.

In the end, I hope the materials presented and their arrangement in various chapters will make the book useful, accessible, and interesting to students, research scholars, teachers, and professional researchers. Although the various chapters have been reviewed by a panel of competent specialists, nonetheless, the final responsibility for what you read here remains mine, and you may confidently attribute to me any errors of omission or commission in these pages. To help me produce an even better text in the next edition, please send your comments and suggestions at *sanju80gon@gmail.com*.

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I wish to acknowledge and place on record the contributions of several people whose cooperation and encouragement made this book possible. I owe my special debt of gratitude to the most senior and learned specialists, including my father Professor T. N. Singh, from whose insights and suggestions I have benefitted greatly and borrowed skills and expertise freely. Among overseas specialists are the services of Professor Roni Aloni, University of Tel Aviv, Israel, for reviewing Chapter 1; Professor J. T. M. Elzenga, Groningen University, the Netherlands, for particularly providing the biography of Abraham Munting as well as reviewing Chapters 2 and 9; Professor Lars H. Wegner, Karlsruhe Institute, Germany, for Chapters 3 and 4; Professor Slavko Komarnytsky, North Carolina State University, USA, for Chapters 5 and 8; Professor Dani Shtienberg, The Volcani Center, Israel, for Chapter 6; Professor Peter Brimblecombe, City University of Hong Kong, for Chapter 7: all of which are gratefully recognized and appreciated. I am heartily indebted to Professor Ulrich Luettge, Darmstadt University of Technology, Germany, and Professor Wolfgang Kundt, University of Bonn, Germany, for their invaluable contributions by way of critical comments, constructive suggestions, and technical editing of the entire manuscript of the book. These acts of selfless service by all the leading experts mentioned above as well as those anonymous reviewers appointed by the Cambridge University Press are once again highly appreciated and they are indeed unforgettable.

I am also grateful to those authors and publishers who have very kindly consented and permitted the use of their copyrighted works and materials for inclusion in this book.

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My special recognition, high appreciation, and sincere thanks go to the publisher Cambridge University Press whose consistent hard work and careful editing contributed much to the clarity and timely publication of the book.

Abbreviations

AAO3	Abscisic aldehyde oxidase 3
ABA	Abscisic acid
ADP	Adenosine diphosphate
AQPs	Aquaporins
AtABA2	*Arabidopsis thaliana* abscisic acid
AtNCEDs	*Arabidopsis thaliana* 9-cis epoxycarotenoid dioxygenases
ATP	Adenosine triphosphate
AtPUP1	*Arabidopsis thaliana* purine permease 1
BOR1	Boron transporter *Arabidopsis thaliana*
Bot1	Boron transporter barley
CK	Cytokinin
CPMCW	Cytoskeleton–plasma membrane–cell wall
CTP	Compensating tissue pressure
DNP	2,4-dinitrophenol
DPIC	Diphenylene iodonium chloride
GSTs	Glandular-secreting types
KCN	Potassium cyanide
MALDI-TOF	Matrix-assisted laser desorption/ionization time-of-flight
MRI	Magnetic resonance imaging
NDRH-2	Narendra Deva Rice Hybrid-2
PEG	Polyethylene glycol
PUP	Purine permease
PVC	Polyvinyl chloride
ROS	Reactive oxygen species
SUTs	Sucrose transporters
TSP	Total soluble protein
WT	Wild-type