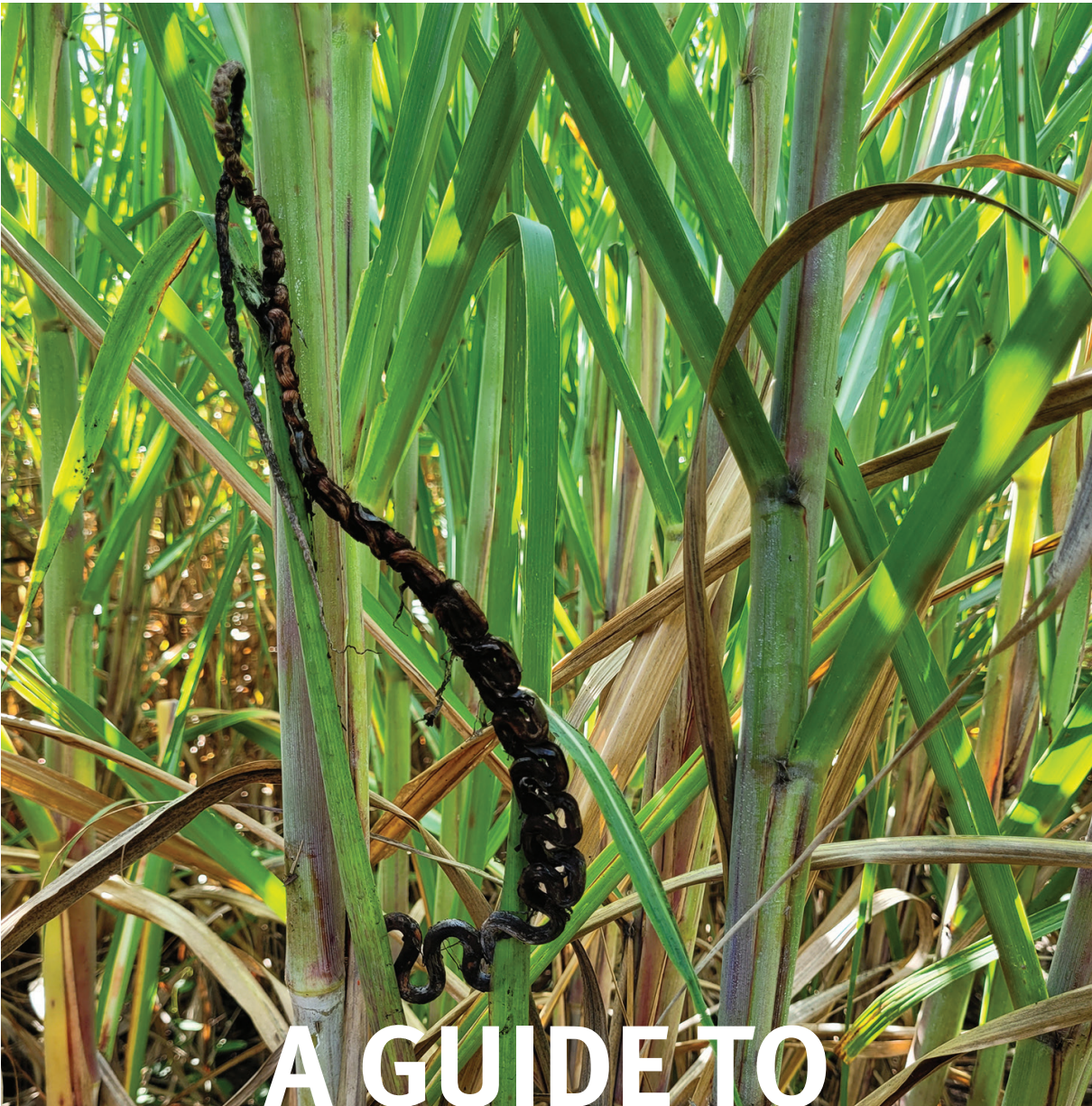




A GUIDE TO SUGARCANE DISEASES

P. Rott, J.-C. Girard, J.H. Daugrois, eds

2nd edition

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A guide to sugarcane diseases

Philippe Rott, Jean-Claude Girard,
Jean Heinrich Daugrois, eds

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Cover: Serpentine-shaped whip produced by *Sporisorium scitamineum*,
the causal agent of smut. Photo credit: Philippe Rott.

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In memory of
Kathryn (Kathy) S. Braithwaite
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and Benham (Ben) E.L. Lockhart
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for their outstanding contributions to sugarcane pathology.

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Foreword

From its centre of origin in New Guinea some 10,000 years ago, sugarcane has spread across diverse geographical zones largely through manmade activities. Today, it is grown on approximately 26 million hectares in 120 countries. Among all the cultivated crops, sugarcane has the largest biomass and is regarded as one of the most efficient natural biofactories. It accounts for 80% of the world's annual sugar production of some 186 million tons and plays an increasing vital role in the production of bioelectricity, biofuel, bioplastics and a growing range of sucrochemicals. It has various attributes to address the societal issues such as food production, climate change, renewable energy, decarbonisation, etc.

If sugarcane has reached such an importance, it is mostly through the result of research and development, innovation and technological advancement. It is worth noting that sugarcane was among one of the first crops to have benefitted from organised research with the British and the Dutch in Barbados and Java in 1886, followed by the creation of research centres in Mauritius, in Hawaii and in Australia in the 1890s. The pioneering initiative stimulated similar activities in other sugarcane growing areas.

Early research efforts focused primarily on the creation of new high yielding varieties, resistant to diseases and pests with improved sucrose content. Disease identification, and disease management strategies ranked high as priorities on the agenda of the research centres. The creation of the International Society of Sugar Cane Technologists (ISSCT) in Hawaii in 1924 marked a turning point, federating global research impetus on sugarcane diseases. The ISSCT created various standing committees, including one devoted to sugarcane diseases. This committee contributed significantly to advancing knowledge on sugarcane pathology and quarantine (referred as biosecurity in the modern context). At each of the 32 ISSCT congresses held to date, sugarcane diseases have been an important component on the agenda.

It is to be recalled that sugarcane diseases have been a serious yield-reducing factor with ratoon stunt as an insidious disease, epidemics of mosaic in the 1920s in the USA, Fiji leaf gall in Australia and gumming in the Mascarenes in the 1960s, smut and brown rust in the Caribbean in the 1970s, yellow leaf in the 1990s, orange rust in Australia in year 2000, to name some occurrences. In addition, new pathogens such as sugarcane bacilliform virus and sugarcane yellow leaf virus have been identified, while several known ones including *Puccinia kuehnii* and sugarcane streak mosaic virus have spread to previously unaffected regions.

Over the years, the Proceedings of ISSCT congresses have served as a rich source of information on sugarcane diseases. To further disseminate knowledge, the ISSCT supported the publications of three books by Elsevier Publishing Co., Amsterdam, The Netherlands, written by sugarcane pathologists. They are *Sugar-Cane Diseases of the World, Volume I* (J.P. Martin, E.V. Abbott and C.G. Hughes, Eds., 1961), *Sugar-Cane Diseases of the World, Volume II* (C.G. Hughes, E.V. Abbott and C.A. Wismer, Eds., 1964) and *Diseases of Sugarcane – Major Diseases* (C. Ricaud, B.T. Egan, A.G. Gillespie Jr and C.G. Hughes, Eds., 1989).

In 1991, ISSCT in collaboration with the FAO and the International Board for Plant Genetic Resources (IBPGR) published *Technical Guidelines for the Safe Movement of Sugarcane Germplasm*. Additionally, from September 1968 to November 1982, the ISSCT published 29 issues of the Sugarcane Pathologists' Newsletter.

In 2000, a practical guide entitled *A Guide to Sugarcane Diseases*, under the helm of P. Rott, Chairman of the Editorial Committee, was published by CIRAD within its series REPERES. This guide provided a very useful resource for sugarcane pathologists in the identification, understanding and practical management of diseases.

Since then, new diseases have emerged in several sugarcane producing areas such as tawny rust caused by the fungus *Macruropyxis fulva* in Africa. In addition, the agents of long known diseases like chlorotic streak described in the 1920s and Ramu stunt in the 1980s have seen major advancement. The causal agent of chlorotic streak was identified as *Phytocercomonas venanans*, a cercozoan, while that of Ramu stunt is a virus, specifically a *Mechlorovirus*. In addition, novel viruses belonging to various genera such as *Mastrevirus*, *Polerovirus*, *Mechlorovirus*, and *Umbravirus* were identified. In parallel, the application of molecular biology has revolutionized disease diagnostics, with tools such as polymerase chain reaction (PCR), reverse transcriptase (RT)-PCR, nested-PCR, multiplex PCR, multiplex RT-PCR, and loop-mediated isothermal amplification (LAMP) now commonly used.

These new developments have prompted a new edition of the *Guide*, led by Philippe Rott, Jean-Claude Girard, and Jean Heinrich Daugrois of CIRAD together with a team of dedicated collaborators. It offers a comprehensive and updated description of some 80 diseases, their cause, geographical distribution, symptoms, diagnosis, strain variation, transmission, host range, epidemiology, economic importance, control, and essential references. The inclusion of photographs of symptoms, pathogens, and vectors enhances its practical value.

I commend the Editors and authors of the chapters for producing this new Edition which will undoubtedly become a vital resource for sugarcane pathologists, researchers and industry professionals worldwide.

Jean Claude Autrey
Sugarcane pathologist and former Director
of the Mauritius Sugar Industry Research Institute (MSIRI)
General Secretary of the International Society
of Sugar Cane Technologists (ISSCT)

Introduction

Philippe Rott, Jean-Claude Girard, Jean Heinrich Daugrois

Since the release of the first edition of the Guide to sugarcane diseases in 2000, new diseases developed in several sugarcane producing countries. For example, tawny rust caused by the fungus *Macruropyxis fulva* was reported for the first time in South Africa. Additionally, the cause of diseases such as chlorotic streak and Ramu stunt was discovered. New viruses infecting sugarcane were uncovered thanks to the progress of molecular methods such as high-throughput sequencing. Several diseases that were limited to a given location increased their geographical distribution. For example, orange rust that was limited to the Asian-Oceania region was reported for the first time in Florida in 2007 and, in subsequent years, the disease spread through most of the American continent. Similarly, sugarcane streak mosaic virus, that was limited to Asia for decades, was found for the first time in the late 2010s in Africa. These examples illustrate the ever-changing nature of sugarcane diseases and consequently the information available regarding the pathogens affecting the sugarcane crop and disease management needs to be updated. A lot of progress has also been made in the areas of disease diagnosis and detection, resulting in the development of various highly performant molecular assays that are being continuously improved. Nevertheless, although diseases can be better diagnosed than ever, their control remains challenging. Thus, the control of sugarcane diseases involving the production and use of resistant varieties, the use of healthy planting material to avoid pathogen transmission, pesticide applications, and movement of germplasm using quarantine facilities continues to evolve.

The objective of this new edition of “A guide to sugarcane diseases” was therefore to provide a new reference book with updated and recent data. More than 80 diseases are described. Each description includes name of the disease, cause, geographical distribution, symptoms, diagnosis, strains of the pathogen, transmission, host range, epidemiology, economic importance, and control. Disease symptoms, their causal agents or pathogens’ vectors are illustrated by numerous photographs. Updated procedures for the safe movement of sugarcane germplasm, common names of sugarcane diseases and their causal agent(s), as well as sugarcane producing countries/locations and their diseases are also included. Each book chapter has been written by one or two experts in the field of sugarcane pathology. We hope that this new book will be a useful new resource for sugarcane and plant pathologists in general, the sugarcane community at large, and any person interested in this subject.



Sugarcane morphology, anatomy and physiology

Jean-Yves Hoarau

This chapter has been updated and rewritten based on the original chapter entitled “Sugarcane morphology, anatomy and physiology” and authored by G. Claude Soopramanien in 2000.

Sugarcane (*Saccharum* spp.) is a monocotyledon belonging to the *Poaceae* family (*Gramineae*) and the *Andropogoneae* tribe.

Sugarcane is a member of the *Saccharum* genus which evolved in South-East Asia from continental areas to Melanesia. The genus is usually divided into six species or horticultural groups all of which are high-order polyploids ($\geq 5x$) (Grivet *et al.*, 2006). Two of them, *S. spontaneum* and *S. robustum*, are wild species with very little juice and sucrose and a high fiber content. They are morphologically well differentiated. *S. spontaneum* ($2n = 40\text{--}128$) has thin stalks, and is diverse in size, ranging from short bushy types to tall types. It has an extensive distribution from the Mediterranean region and Africa to Indonesia and Japan. *S. robustum* ($2n = 60\text{--}80$) has thicker long stalks and is most likely native to Southeast Asia, southeast of Sulawesi. *S. officinarum* ($2n = 80$), also known as ‘the noble cane’, is the sugar-producing species. It was domesticated from *S. robustum* around 8000 BC by Melanesian people in Papua New Guinea for its thick, juicy and sweet stalks which were grown for chewing. Two groups of old cultivars, *S. barberi* ($2n = 81\text{--}124$) and *S. sinense* ($2n = 116\text{--}120$), formerly grown in India and China, respectively, have an interspecific origin between *S. officinarum* and *S. spontaneum*. *S. edule* ($2n = 60\text{--}122$), cultivated for its edible aborted inflorescences in subsistence gardens from New Guinea to Fiji, represents a marginal group derived from *S. robustum*.

Modern sugarcane varieties ($2n = 100\text{--}130$) currently grown worldwide are artificial interspecific hybrids between the ‘noble’ species *S. officinarum* and the wild species *S. spontaneum*. They are the result of breeding schemes involving interspecific crosses followed by several generations of backcrosses on the ‘noble’ species or on hybrids, and subsequent crosses between advanced backcross products. As a result, the genome of modern interspecific varieties comes from *S. officinarum* (75–85%) and *S. spontaneum* (15–25%). The two ancestral progenitors of modern interspecific varieties differ markedly in many morphological and agronomic traits (Figure 1):

- *S. spontaneum* is a highly vigorous species which develops numerous tillers from a large underground stool with a deep, dense root system capable of producing rhizomes.

It has fibrous, thin stalks (5 to 10 mm in diameter) with a hard rind surrounding a small dry pith zone frequently hollow in its central part. The leaves consist of narrow strips, often reduced to the central midrib. This species often has a high level of resistance to many diseases but can exhibit some variation for susceptibility. It is composed of highly polymorphic clones, enabling it to adapt to a wide variety of environments and abiotic stresses (some of its clones are found growing under drought stress in deserts, water-logged conditions in marshes and under a wide range of temperatures from the hottest tropics to the coldest subtropics).

– *S. officinarum* produces relatively few stalks (6 to 10 per clump) with large diameters (4 to 8 cm), completely filled with a juicy, sweet, low-fiber pith. The leaves are broad and droop under their own weight, making it easy to detach from the stalk. The species has a relatively shallow root system compared to *S. spontaneum*. It requires a lot of water and sunshine to grow and is strictly tropical. The species is susceptible to most major sugarcane diseases.

Cultivation of old *S. officinarum*, *S. barberi* and *S. sinense* varieties stopped at the beginning of the 20th century after severe disease epidemics including mosaic and sereh diseases. They were replaced by modern interspecific varieties (*S. officinarum* × *S. spontaneum*) which were first bred for disease resistance. These have also proven to be far superior in terms of cane and sugar yields. *S. officinarum* transmitted its high sucrose content and good milling characteristics, while *S. spontaneum* contributed physiological traits that allowed modern hybrids to be grown in diverse, frequently unfavorable, environments with multiple harvests. The ability of modern varieties to adapt to a wider range of environments has contributed to the worldwide expansion of sugarcane production areas over the last hundred years.

Sugarcane has specialized anatomical and physiological features that enable it to accumulate large quantities of sucrose. The features described in this chapter are those of modern interspecific varieties (*Saccharum* spp.). This review describes the anatomy of sugarcane organs and tissues in relation to their functional roles and the physiology of the plant through its successive stages of development from tillering, canopy development, growth and elongation to flowering and ripening.

The diseases described in this book can affect one or several organs of sugarcane (leaves, stems or roots) during the plant's life cycle. Severity of symptoms observed for each organ will depend on the pathways of infection and colonization patterns of pathogens within the host plant, environmental conditions, and the level of disease resistance of a sugarcane variety. In order to recognize sugarcane plants affected by a disease (if possible, at an early stage of infection), and take appropriate control measures, knowledge of the morphology, anatomy and physiology of sugarcane is very important. This knowledge will help (i) to analyze field observations associated with a phytosanitary issue, (ii) to investigate the interactions between sugarcane and a pathogen, (iii) to study and understand the epidemiological context, and (iv) to better assess the disease impact on sugarcane organs/tissues and predict yield losses. This introduction chapter therefore aims to provide a general description of the sugarcane morphology, anatomy and physiology. For further information, the reader is referred to the publications in the references list.

Morphology and anatomy

The general morphology of sugarcane is that of a large perennial bunch grass. Plant anatomy resembles that of other C_4 grasses such as maize or sorghum. As with other grasses, the stalk is composed of repeating phytomeric units containing a node, an attached



Figure 1. Morphology comparison of *Saccharum officinarum*, *S. spontaneum*, and a modern interspecific hybrid. *S. spontaneum* produces numerous thin and highly fibrous stalks containing little or no sucrose, while *S. officinarum* develops a smaller number of thick, juicy and sweet stalks. Modern interspecific varieties have intermediate morphological traits between their two ancestral progenitors (J.-Y. Hoarau).

leaf, and an internode with the youngest units at the top of the stalk. As internodes grow and age, they progressively accumulate more sucrose. When there is a sufficient number of mature internodes with high sucrose content, the cane is harvested by cutting the stalks at the base and removing the immature top. After each periodic harvest, a new crop cycle begins, with new shoots sprouting from buds in the below-ground parts of the harvested stalks. This process is known as ratooning. Sugarcane is grown on a semi-perennial basis over several successive cycles, each lasting from 12 to 18 months, depending on the growing environment and the cropping system. Sugarcane is distinguished from many common grasses by its long, indeterminant vegetative growth period, which translates into a large plant size and high biomass per unit area.

The root system

Sugarcane is usually propagated from stalk cuttings consisting of one or several nodes. A first root system develops from primordia in the root band region of the stalk nodes. These sett roots are thin and highly branched, and absorb water and nutrients to feed the young, developing shoot (Figure 2A). They are present in the first weeks of development of the shoots and gradually die back. Their function is taken over by shoot roots emerging from primordia within the root bands of underground nodes of young shoots (Figure 2B). Shoot roots are more robust and thicker (five to ten times) than sett roots. They represent the persistent root system that supports the plant's development and growth throughout its life cycle. Cane harvest at the end of the cycle causes a partial die-back of this root system. As new shoots emerge from the clump's underground nodes, new roots develop at their base. Partial survival of the former root system provides protection against drought during the early stages of growth of the ratoon crop.

The anatomical organization of young sugarcane roots resembles that of other grasses. In a cross-section, concentric cylinders of tissue are made of different cell types.

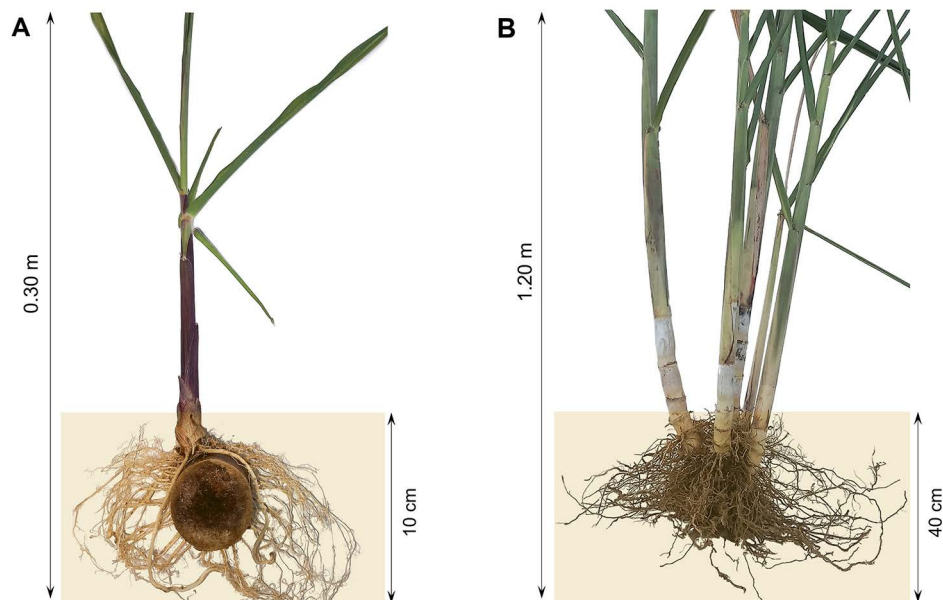


Figure 2. The root system of sugarcane variety R579 after soil washout. (A) The fine sett roots three weeks after the germination of a single-eye stalk cutting in a small pot. (B) The thick, dense shoot roots in a five-month-old sugarcane clump removed from the field (J.-Y. Hoarau).