COTTON PHYSIOLOGY

NUMBER ONE
THE COTTON FOUNDATION
REFERENCE BOOK SERIES

Edited by
Jack R. Mauney
and
James McD. Stewart

COTTON PHYSIOLOGY

THE COTTON FOUNDATION

Reference Book Series

The Cotton Foundation was created in 1955 to foster innovative research and education not covered by other private or public agencies. It is supported by many of America's finest agri-industries and financial institutions, including banks, cotton magazines, and manufacturers of machinery, chemicals and other inputs used in cotton production, processing and marketing. With this effective partnership of agribusiness firms and the cotton industry through The Foundation, greater strength is marshalled on important cotton problems.

The goal of The Foundation is to enhance markets for the benefit of the U.S. cotton industry as well as its corporate suppliers. Funds granted to The Foundation go entirely to support research and educational programs. Staffing is provided by the National Cotton Council and offices are in the Council's building in Memphis, Tennessee.

The Foundation is pleased to initiate a program to publish a series of cotton reference books with this volume, **COTTON PHYSIOLOGY,** being the first. Second and third books in the series, **WEEDS OF COTTON: Characterization and Control** and **COTTON INSECTS AND MITES: Characterization and Management,** are in early developmental stages. Plans are to publish several others in this series.

The Cotton Foundation
1918 North Parkway
Memphis, Tennessee 38112

ACKNOWLEDGEMENT

Publication of this book was made possible by a grant to The Cotton Foundation from BASF Corporation. BASF is a major supplier to the cotton industry and supports programs for cotton through The Cotton Foundation.

BASF Corporation is a diversified chemical company with a strong tradition of technological excellence. The firm is part of the worldwide BASF Group. Based in West Germany, the BASF Group of 111 companies ranks among the world's largest in the manufacture and marketing of inorganic and organic industrial chemicals, coatings, paints, vitamins, dye-stuffs, pigments, pharmaceuticals, plastics, magnetic recording media and other specialty chemicals. Total annual sales are in excess of $15 billion.

The BASF commitment to agriculture is typified by the company's 1911 development of the Nobel prize-winning technique that allows mass production of affordable fertilizers. Following the establishment of BASF Corporation in the U.S., the company developed the first plant regulator available to American cotton growers. Cotton plants treated with Pix® plant regulator are more compact, resulting in interrelated benefits of higher boll numbers, early maturity, reduction of boll rot and control of rank growth. In addition, BASF Corporation manufactures Poast® herbicide, a postemergence product for grass control that offers cotton growers added flexibility in their weed control programs.

BASF Corporation is proud to be a member of The Cotton Foundation and sponsor of **COTTON PHYSIOLOGY,** the first book in The Cotton Foundation's cotton reference book series. The sponsorship is a reflection of the company's belief that continued support of the development of technologies and materials that promote the production of more cost-effective, higher yielding cotton, will make a stronger cotton industry.

COTTON PHYSIOLOGY

Editors
JACK R. MAUNEY AND JAMES McD. STEWART

Executive Editor and Publishing Coordinator
JAMES M. BROWN

Number One
THE COTTON FOUNDATION
REFERENCE BOOK SERIES

The Cotton Foundation, Publisher
Memphis, Tennessee, U.S.A.
1986

The Cotton Foundation
1918 North Parkway
Memphis, Tennessee 38112, U.S.A.

Library of Congress Cataloging-in-Publication Data

Cotton physiology.

(The Cotton Foundation reference book series; no. 1)
Includes bibliographies and index.
1. Cotton—Physiology. I. Mauney, Jack R., 1928- II. Stewart, James McD., 1941- III. Series.

SB249.C7938 1986 583'.17 86-16698

ISBN 0-939809-00-1 (The Cotton Foundation Reference Book Series)
ISBN 0-939809-01-X (Number One)

Published 1986; reprinted 1987, 1991

Photograph by James McD. Stewart

Photograph by William E. Barksdale

TABLE OF CONTENTS

SECTION I

DEVELOPMENT OF THE PLANT

SECTION II

PHOTOSYNTHATE PRODUCTION & DISTRIBUTION

SECTION III

BOLL DEVELOPMENT

SECTION IV

SEED AND GERMINATION

SECTION V

SPECIAL TOPICS

FOREWORD

From virtually every aspect, cotton is one of the most interesting higher organisms in the plant kingdom. It is rather unique in that it produces both fiber and food.

In its wild state, cotton is basically a perennial woody shrub in a semi-desert habitat. As an economic crop, it is now grown in the United States as a herbaceous annual under both semi-arid and humid conditions. Cotton also has been grown commercially as a perennial in areas of this country with mild winters. Only a few years ago about 50,000 acres of stub cotton were grown in Arizona. It has since been banned because it intensifies boll weevil and pink bollworm problems. However, in some parts of the world, some cotton is still grown commercially as a perennial.

Cotton belongs to the genus *Gossypium* which is in the Malvaceae or Mallow family. Other members of this family include okra, hollyhock, rose of sharon, and even such plants as teaweed, spurred anoda, and velvetleaf that are weed pests in cotton. The 39 species in the genus *Gossypium* are quite diverse. Only four of them produce commercial-type lint. *G. hirsutum*, to which the upland varieties belong, and *G. barbadense*, which includes the extra long staple or Pima varieties, are the only ones grown commercially in the United States.

Even though cotton is grown as an annual, its reproductive and growth habits are controlled by a "perennial" physiological system programmed for maximum seed production and survival over a number of years rather than just one.

Compared with most crop plants, cotton adapts quite well to adverse conditions. For example, it is considerably more tolerant to high salinity soils than corn. Cotton's vegetative and fruiting balance adjusts both during and after periods of stress (moisture stress, light stress, etc.) preserving the potential for good yield if sufficient growing season remains.

One interesting physiological aspect of cotton is the way fibers begin and develop. A single epidermal cell of the seed gives rise to a fiber. Some cells produce lint fibers and others shorter fuzz fibers. A relatively small percentage of the epidermal cells on a seed develop into fiber even though they all have the same genetic makeup. What controls which ones develop into fibers? What determines which fibers will be lint and which will be fuzz fibers? Someday we will have the answers to these and other questions about cotton. With such knowledge, we may be able to trigger initiation of fibers from more of the epidermal cells. This presumably projects to higher yields, but other factors such as inadequate photosynthate might limit the expression of more fibers per seed to higher yields.

There are numerous other interesting facets about cotton's physiology. For example, a lint fiber's elongation period lasts up to about 18 to 20 days postanthesis. After elongation ceases, deposition of secondary fiber wall material begins. Also, at about 18-20 days postanthesis, the endosperm begins to disappear. It is completely gone by the time the boll opens.

With some varieties, the lint and fuzz fibers are restricted to specific and sometimes separate areas of the seed surface. With the so-called naked seed varieties, the fuzz fibers are totally absent. Some wild species produce no fibers.

The physiological and biochemical events that take place in cotton's growth and development are highly regulated—much as if cotton is programmed by a highly sophisticated, built-in computer.

It is no wonder that many scientists working with cotton get caught up in its mystique and become deeply dedicated to unlocking its mysteries by finding the correct physiological/biochemical keys.

The National Cotton Council is pleased to have played a significant role in initiating The Cotton Foundation Reference Book Series and is particularly happy that the first book in the series is on cotton physiology.

The usefulness of **COTTON PHYSIOLOGY** as a reference book goes beyond the traditional researcher, teacher, and student users. Private agricultural consultants and representatives of the agricultural chemicals industry will find it to be a valuable source of information. Modern-day cotton producers also will find this book useful. Today's educated and innovative producers want to know more than just "what to do" and "when to do it." They want to know the reasons for doing things at certain times. They are interested in the cotton plant's fruiting and vegetative development as related to environmental conditions, cultural practices, etc. They realize that the more that is known about the cotton plant, the more successful they will be in culturing it as a commercial crop.

The National Cotton Council and The Cotton Foundation are indebted to Drs. Jack R. Mauney and James McD. Stewart, two outstanding scientists who have dedicated so much time and effort as editors in bringing this book to fruition. The Council and Foundation also recognize the major contributions of the 48 other scientists who were authors of the 40 chapters.

James M. Brown
Manager, Production Technology
National Cotton Council

PREFACE

The cotton plant is unique among major agricultural crops in the number of its actual and potential uses. Not only does it produce the fiber with which everyone is intimately familiar as a consumer, but it also produces a high quality oil and a protein meal equivalent to or better than soybean. The cotton plant is also unique for its service as a multifaceted experimental system. Notable in this vein are: (1) the early work on abscission, defoliation and the discovery of abscisin; (2) studies on the physics and biochemistry of cellulose deposition in fibers; (3) mathematical simulation of crop growth and productivity; (4) the ultramicrographic description of pollen tube growth and fertilization; (5) the *in vitro* culture of ovules and fibers; and (6) the *in ovulo* culture of interspecific hybrid embryos. Cotton continues to be used as a model plant in the molecular biology of embryogenesis and gene regulation, in crop modeling, in cellulose synthesis and in cell differentiation. Many individuals have spent their careers studying various aspects of cotton growth and production, but progress has been slow and many perplexing problems remain.

Cotton does not readily yield its secrets. Anecdotally, it is said that there are two types of individuals who have worked with cotton. There are those who start a research program and become so frustrated with the crop that they will never work with it again. Then, there are those who become so fascinated with the peculiarities and idiosyncracies of the plant that they will never work with anything else.

It is in the spirit of and for the enthusiasts that we have attempted to create this book which is the culmination of several years of effort, hope and frustration. The inception of the idea for a comprehensive treatise on cotton physiology began in early 1978 during informal discussions among Earl King, who was USDA's Research Leader for Cotton Physiology at Stoneville, Mississippi, Jim Brown of the National Cotton Council, and the two of us. We recognized that there was a large body of information on cotton physiology, but that there was no source or reference from which one could readily obtain information. Those discussions led to the decision to conduct a series of symposia that would concentrate on specific aspects of the life history of the cotton plant. The intent was to generate a series of review and research papers that would provide the bulk of a reference book.

The format of the symposia conducted over a four-year period as a part of the Cotton Physiology Conference program during the Annual Beltwide Cotton Conferences strongly influenced the character of the book. Each year, three or four individuals considered as experts in the specific topic areas were asked to make major presentations. They, in turn, selected 2 to 4 additional researchers to provide expertise in related areas that deserved emphasis. All individuals submitted manuscripts covering their assigned topics. Our decision was to make each contribution a chapter. Consequently, considerable variety in length and content will be found in the various texts. At the end of the fourth symposium, all authors were given an opportunity to update their contributions. Since there were obvious

deficiencies in the subjects covered, we asked for additional chapters from experts in the deficient areas. The final result is contained herein.

We hope this book will serve as a background resource and starting point for future research into the physiology of the cotton plant. Its physical bulk and its more than 2200 citations should be an eloquent testimony to the complexity of the developmental processes in the cotton plant and, by inference, all plants. Attempts to reduce this plant to simplistic experiments and unequivocal statements about its behavior are naive at best and foolhardy at worst. In the truest sense, the crop is a four-dimensional entity. There is an immediacy of its daily reaction, but it has a distinct "memory" of its past (both recent and evolutionary) which is the basis for its future. Until physiologists and agronomists can integrate those reactions in the same way the plants do, our understanding will lack the dimension of time which has such a profound impact on the productivity of the crop.

Though the primary use of symposia books of this type is as a reference gathering dust until a specific question is asked, we think that it can serve usefully as a mystery story read from cover to cover. The mystery is, "What is a cotton plant?" In much the same way as the blind professors describing the elephant, each author experiences the cotton plant from a different perspective. Collecting their accounts so that a composite picture of the whole emerges is the purpose of this treatise. All who want to know the plant completely should be anxious to read every facet.

We are indebted to the many authors who contributed their time and expertise without compensation to make the symposia so successful. Ultimately, this resource volume is a tribute to them and to cotton physiology.

Jack R. Mauney
James McD. Stewart
Editors

CONTRIBUTORS

	Current Address if Different
Dr. Basil Acock Plant Physiologist USDA, Agricultural Research Service Crop Simulation Research Unit Mississippi State University Mississippi State, MS 39762	
Dr. Donald N Baker Agronomist USDA, Agriculatural Research Service Crops Simulation Research Unit Mississippi State University Mississippi State, MS 39762	
Dr Charles C. Baskin Associate Professor and Extension Specialist Department of Agronomy Mississippi State University Mississippi State, MS 39762	
Dr. Alois A. Bell Pathologist USDA, Agricultural Research Service National Cotton Pathology Research Laboratory P.O. Drawer JF College Station, TX 77841	
Dr. C.R. Benedict Professor Department of Plant Sciences Texas A & M University College Station, TX 77843	Department of Biochemistry & Biophysics Texas A & M University College Station, TX 77843
Dr. Jerry D. Berlin Professor Department of Biology Texas Tech University Lubbock, TX 79423	
Dr. Luther S. Bird Professor Department of Plant Sciences Texas A & M University College Station, TX 77843	(Retired)

Stephen J. Bortman
Graduate Student
Department of Botany & Microbiology
Arizona State University
Tempe, AZ 85287

Dr. James M. Brown
Manager, Production Technology
National Cotton Council
P.O. Box 12285
Memphis, TN 38182

George W. Cathey
Plant Physiologist
USDA, Agricultural Research Service
Cotton Physiology & Genetics Research
Delta States Research Center
P.O. Box 225
Stoneville, MS 38776

Dr. John P. Cherry
Chemist
USDA, Agricultural Research Service
Southern Regional Research Center
1100 Robert E. Lee Boulevard
New Orleans, LA 70179

Director
Northeastern Regional Research Center
600 E. Mermaid Lane
Philadelphia, PA 19118

John S. Choinski, Jr.
Graduate Student
Department of Botany & Microbiology
Arizona State University
Tempe, AZ 85287

Assistant Professor
Department of Biology
University of Central Arkansas
Conway, AR 72032

Dr. Meryl N. Christiansen
Plant Physiologist
USDA, Agricultural Research Service
Plant Physiology Institute
Agricultural Research Center
Beltsville, MD 20705

(Retired)

Prof. Edmond A.L. DeLanghe
Lab. Tropische Plantenteelt
Katholieke Universiteit Leuven
Kardinaal Mercierlaan, 92
3030 Heverlee, BELGIUM

Dr. James C. Delouche
Professor & Director of State
Seed Laboratory
Department of Agronomy
Mississippi State University
Mississippi State, MS 39762

Dr. Julius W. Dieckert
Professor
Dept. of Biochemistry and Biophysics
Texas A & M University
College Station, TX 77843

Department of Plant Pathology
& Microbiology
Texas A & M University
College Station, TX 77843

Mary C. Dieckert
Research Associate
Texas A & M Research Foundation
Texas A & M University
College Station, TX 77843

Dr. Carl F. Ehlig
Plant Physiologist
USDA, Agricultural Research Service
4151 Highway 86
Brawley, CA 92227

(Retired)

Dr. James L. Fowler
Associate Professor
Department of Crop & Soil Sciences
New Mexico State University
Las Cruces, NM 88003

Dr. Paul A. Fryxell
Botanist
USDA, Agricultural Research Service
Cotton & Grain Crops Genetics Research
P.O. Drawer DN
College Station, TX 77840

Dr. Glenn A. Galau
Assistant Professor
Department of Botany
University of Georgia
Athens, GA 30602

Dr. Jack R. Gipson
Associate Professor
Department of Plant & Soil Science
Texas Tech University
Lubbock, TX 79413

Dr. Gene Guinn
Plant Physiologist
USDA, Agricultural Research Service
Western Cotton Research Laboratory
4135 E. Broadway Rd.
Phoenix, AZ 85040

Dr. John M. Halloin
Plant Physiologist
USDA, Agricultural Research Service
National Cotton Pathology Laboratory
P.O. Drawer JF
College Station, TX 77841

Dr. Norman Hopper
Associate Professor
Department of Plant & Soil Science
Texas Tech University
Lubbock, TX 79409

Dr. Richard Jensen
Professor
Department of Biochemistry
University of Arizona
Tucson, AZ 85721

Dr. Howard E. Joham (Retired)
Professor and Head
Department of Plant Sciences
Texas A & M University
College Station, TX 77843

Dr. Lynn A. Jones
Director, Research & Education
National Cottonseed Products Assoc., Inc.
P.O. Box 12023
Memphis, TN 38112

Dr. Wayne R. Jordan
Professor
Texas Agricultural Experiment Station
Blackland Research Center
Temple, TX 76501

Director
Water Resources Institute
Texas A & M University
College Station, TX 77843

Dr. Russel J. Kohel
Geneticist
USDA, Agricultural Research Service
Cotton and Grain Crops Genetic Research
P.O. Drawer DN
College Station, TX 77840

Dr. K. Kosmidou-Dimitropoulou
Plant Physiologist
Hellenic Cotton Board
150 Syngrou Ave.
Athens (404). GREECE

Dr. Dan R. Krieg
Professor
Department of Plant & Soil Science
Texas Tech University
Lubbock, TX 79409

Dr. Donald T. Krizek
Plant Physiologist
USDA, Agricultural Research Service
Plant Stress Laboratory
Agricultural Research Center
Beltsville, MD 20705

Dr. Otto R. Kunze
Professor
Department of Agricultural Engineering
Texas A & M University
College Station, TX 77843

Dr. Harry R. Leffler
Plant Physiologist
USDA, Agricultural Research Service
Cotton Physiology & Genetics Research
Delta States Research Center
Stoneville, MS 38776

DeKalb-Pfizer Genetics
3100 Sycamore Rd.
DeKalb, IL 60115

Dr. Jack R. Mauney
Plant Physiologist
USDA, Agricultural Research Service
Western Cotton Research Laboratory
4135 E. Broadway Rd.
Phoenix, AZ 85040

Dr. Bobby L. McMichael
Plant Physiologist
USDA, Agricultural Research Service
Plant Stress & Water Conservation
Research
Southern Plains Cotton Research
Laboratory
Rt. #3
Lubbock, TX 79401

Dr. Jan A. Miernyk
Graduate Student
Department of Botany & Microbiology
Arizona State University
Tempe, AZ 85287

Chemist
USDA, Agricultural Research Service
Northern Regional Research Center
1815 N. University St.
Peoria, IL 61604

Dr. William H. Powell
Agronomist
National Cottonseed Products Assoc., Inc.
P.O. Box 12023
Memphis, TN 38112

3147 South Fairfield Drive
Tempe, AZ 85282

Dr. Jerry E. Quisenberry
Geneticist
USDA, Agricultural Research Service
Cropping Systems Research Laboratory
Rt. #3
Lubbock, TX 79401

Dr. John W. Radin
Plant Physiologist
USDA, Agricultural Research Service
Western Cotton Research Laboratory
4135 E. Broadway Rd.
Phoenix, AZ 85040

Dr. Harmon H. Ramey, Jr.
Geneticist
USDA, Agricultural Research Service
Cotton Quality Laboratories
University of Tennessee
Knoxville, TN 37996

Chief, Fiber Technology Branch
USDA, AMS, Cotton Division
4841 Summer Avenue
Memphis, TN 38112

Dr. Randy Rowland
Plant Physiologist
USDA, Agricultural Research Service
Plant Physiology Institute
Agricultural Research Center
Beltsville, MD 20705

Dr. A. Michael Schubert
Assistant Professor
Department of Plant Sciences
Texas A & M University
College Station, TX 77843

Associate Professor
Plant Disease Research Station
Texas A & M University
Yoakum, TX 77995

Dr. James McD. Stewart
Plant Physiologist
USDA, Agricultural Research Service
Department of Plant & Soil Science
University of Tennessee
Knoxville, TN 37996

J.F.M. Sung
Research Associate
Department of Plant & Soil Science
Texas Tech University
Lubbock, TX 79409

Dr. Robert O. Thomas
Plant Physiologist
USDA, Agricultural Research Service
Delta States Research Center
Stoneville, MS 38776

Dr. Richard N. Trelease
Professor
Department of Botany & Microbiology
Arizona State University
Tempe, AZ 85281

Dr. Gordon R. Tupper
Agricultural Engineer
Delta Branch Experiment Station
P.O. Box 96
Stoneville, MS 38776

Robert W. Wallace
Research Associate
Dept. of Biochemistry and Biophysics
Texas A & M University
College Station, TX 77843

Dr. Donald F. Wanjura
Agricultural Engineer
USDA, Agricultural Research Service
Cropping Systems Research Laboratory
Rt. 3
Lubbock, TX 79401

Professor & Altheimer
Chair for Cotton Research
& Development
Department of Agronomy
University of Arkansas
Fayetteville, AR 72701

Agronomy Department
Nat'l. Chung Hsing University
Taichung, TAIWAN
Republic of China

(Retired)

Department of Pharmacology
University of Alabama
College Station
Birmingham, AL 35294