

*Tropical and Subtropical
Agriculture*

VOLUME

1

Tropical and Subtropical Agriculture

Volume I

J. J. Ochse

Consultant, Tropical and Subtropical Agriculture; Research Consultant in Economic Botany, University of Miami, Coral Gables, Florida

M. J. Soule, Jr.

Associate Professor of Fruit Crops, University of Florida, Gainesville, Florida

M. J. Dijkman

Professor of Applied Tropical Botany and Genetics, University of Miami, Coral Gables, Florida

C. Wehlburg

Assistant Plant Pathologist, University of Florida, Everglades Experiment Station, Belle Glade, Florida

New York

THE MACMILLAN COMPANY

1961



Preface

The writers have felt for a number of years that there was a great need for a brief but reasonably comprehensive book on tropical and subtropical crops. As originally contemplated, it dealt only with selected horticultural and agronomic subjects. However, as the writing progressed, it soon became evident that broader coverage of allied material would make the treatise more useful to the reader whether he be a student in college just beginning his career, a plantation manager or small farmer with some experience, a technician specializing in certain phases of a given crop, or an administrator whose responsibilities include land use development and evaluation of general agricultural policy, particularly in the underdeveloped countries of the tropics and subtropics. There is, of course, ample justification for including a wide range of crops. Despite the trend toward specialization in response to demands for greater uniformity of agricultural products, there has been a growing diversification on plantations and small farms to lessen the impact of crop failures, fluctuating prices, and changing market requirements. Crop plants, especially many ideally suited for culture in the tropics or subtropics, afford a virtually untapped reservoir of raw materials for modern technology. The present-day horticulturist or agronomist not only must know more about each crop with which he deals, but he also must have a working knowledge of an increasing number of them. At the same time, the pressures of growing demand and population in many areas make it necessary to utilize every means possible to increase the productivity of the present cultivated land and to reclaim territory from forests, swamps, deserts, and mountains. More than ever in the past, the horticulturist or agronomist in the tropics or subtropics must have a thorough understanding not only of crops but also of the other components of the agricultural environment.

The first portion of the book represents the firm belief of the writers that horticulturists or agronomists should have the broadest

possible background in climatic factors, formation of soils, soil fertility, soil management, cultural practices, control of diseases and other pests, crop improvement, economic possibilities for the future, and the food value of tropical crops. There is no pretense to completeness in this general section, as each of these subjects is a field in itself. It is hoped, however, that sufficient material is included to enable the reader to gain an adequate appreciation of their importance with respect to the production of crops. Selected references are given at the end of each chapter so that the reader can delve more deeply into topics of interest.

About three quarters of the book is devoted to descriptions of the various crops. The list of plants which could have been included is almost endless; therefore it was necessary from the beginning to select certain ones for treatment. These were chosen partly on the basis of their world-wide importance and partly to afford representation to different areas of the tropics and subtropics. In a number of instances, notably fruit crops, species virtually unknown outside of a limited region were included because of their merit. On the other hand, species of equal promise have sometimes been excluded by reason of space limitations. The description of each crop follows a similar pattern: general information including world production, botany, botanical description, varieties, breeding and selection, climatic and soil requirements, culture, harvesting, processing, uses, and lists of diseases and other pests. Some or all of these sections have been combined in the case of minor crops. In others, additional ones such as flower biology, pollination, or future possibilities have been included. As in the general part of the book, selected references are given at the end of the chapters. Descriptions of certain of the oil crops, fiber crops, and field crops have purposely been made short. Many of these like the soybean, peanut, sesame, cotton, rice, maize, sorghum, and tobacco are grown over such vast areas and under such diverse conditions that to do them adequate justice would require a separate volume for each. Fortunately, there is a large body of readily available information on all of these crops.

The purpose of this book as stated above was to collect together a body of information about selected tropical and subtropical crops and allied subjects in brief yet reasonably comprehensive form. The writers feel that there is a further purpose without which no book can achieve its full value; namely, to stimulate the reader's

interest sufficiently for him to explore the literature. There are several reasons for this: First, the writers recognize only too well that space has precluded the inclusion of numerous details. Second, there are many other crops which could be studied and grown to advantage, for example plants producing various drugs. Third, and most important, agricultural science is dynamic, as witness the changes which have taken place in the past 15 years. There is every reason to assume that these will continue and accelerate in tempo. The reader should, therefore, keep abreast of current information in his field by constant perusal of periodicals and other sources.

This book is the result of the combined efforts of four men with diverse backgrounds. Primary responsibility for the chapters was divided as follows: M. J. Dijkman contributed the articles on crop improvement (Chapter 6), tea, rubber, and cinchona, as well as part of cacao and the chapters on soil fertility (4) and soil management (5). C. Wehlburg wrote the article on sugar cane and furnished the illustrations used therein. J. J. Ochse and M. J. Soule, Jr., contributed the remainder. The latter also acted as editor for the entire book. All drawings not otherwise credited were made by M. J. Dijkman.

Botanical descriptions of the crops were derived from four principal sources: *Fruits and Fruit Culture in the Dutch East Indies* and *Vegetables of the Dutch East Indies*, by J. J. Ochse, and *Standard Cyclopædia of Horticulture* and *Manual of Cultivated Plants*, by L. H. Bailey. Botanical names, except citrus, follow those given in the last-named reference. Those of citrus follow names given by W. T. Swingle in *The Botany of Citrus*, Chap. IV, Vol. I, of *The Citrus Industry*, edited by H. J. Webber and L. D. Batchelor. Data on world production of the various crops were obtained principally from *Yearbooks of Food and Agricultural Statistics*, published by the Food and Agriculture Organization of the United Nations, Rome, Italy.

Many countries, particularly in Africa, have changed their political status, and in many cases their names, while this book was being completed. With few exceptions, the names applied to countries prior to 1956 have been used throughout the text, since these were readily available in published material. The principal changes to date are listed here: French Morocco = Morocco (1956); French Tunisia = Tunisia (1956); Anglo-Egyptian Sudan = Sudan (1956);

Gold Coast (British) = Ghana (1957); French West Africa = Mauretania, Senegal, Ivory Coast, Sudanese Republic, Upper Volta, Dahomey, Niger (1958, French Community), Guinea (1958, independent), and Republic of Togoland (1960, independent); French Equatorial Africa = Chad, Central African Republic, Gabon, Republic of the Congo (1958, French Community), and Cameroon (1960, independent); Belgian Congo = Congo (1960); Madagascar = Malagasy Republic (1958, French Community); Nigeria (British) = Nigeria (1960); Northern Rhodesia, Southern Rhodesia, and Nyasaland = Federation of Rhodesia and Nyasaland (1956). The Hawaiian Islands became the fiftieth state of the United States in 1959.

The metric system of weights and measures is used in many parts of the tropics and subtropics and consequently, with a few minor exceptions, has been employed throughout the book. Most English-speaking countries, however, adhere to the British or United States systems. Rather than to encumber the text with a dual system, a table is presented following this Preface to facilitate conversion of the various units.

Finally, the writers wish to express their heartfelt appreciation to Miss Helen Louise Dudak, Orlando, Florida, for typing the manuscript.

Gainesville, Florida
May, 1960

J. J. Ochse
M. J. Soule, Jr.
M. J. Dijkman
C. Wehlburg



Conversion Factors

Length *

1 millimeter (mm.) = 0.0394 inch	1 inch (in.) = 2.54 centimeters = 25.4 millimeters
1 centimeter (cm.) = 0.394 inch	1 foot (ft.) = 30.48 centimeters
1 meter (m.) = 39.37 inches = 3.281 feet	1 yard (yd.) = 0.914 meter
1 kilometer (km.) = 3281 feet = 0.621 mile	1 mile (mi.) = 1.609 kilometers = 5280 feet

Area

1 hectare (ha.) = 2.4711 acres	1 acre (A.) = 0.4047 hectare
1 square meter (sq. m.) = 10.764 square feet	1 square foot (sq. ft.) = 0.0929 square meter
1 square centimeter (sq. cm.) = 0.1550 square inches	1 square inch (sq. in.) = 6.452 square centimeters

Weight

1 gram (g.) = 0.0353 avoirdupois ounce	1 avoirdupois ounce (oz.) = 28.35 grams
1 kilogram (kg.) = 2.2046 pounds = 1000 grams	1 pound (lb.) = 0.4536 kilogram
1 quintal (q.) = 220.46 pounds = 100 kilograms	1 hundredweight, short (cwt.) = 45.36 kilograms = 100 pounds

* Approximate values of 1 inch = 2.5 cm. or 1 meter = 40 inches are frequently used where exact figures are not necessary.

Weight (cont'd)

1 metric ton (m. ton)	1 hundredweight, long (cwt.)
= 2204.6 pounds	= 50.8 kilograms
= 1.1023 short ton	= 112 pounds
= 0.984 long ton	1 short ton (ton) = 0.9072 met-
= 1000 kilograms	ric ton = 2000 pounds
	1 long ton (l. ton) = 1.0161 met-
	ric tons = 2240 pounds

Capacity

1 milliliter (ml.) = 0.03382 fluid ounce	1 fluid ounce (oz. fl.) = 29.573 milliliters
1 liter (l.) = 1.057 U. S. quarts	1 fluid quart (qt.) = 0.9463 liters
= 0.2642 U. S. gallon	1 U. S. gallon (gal.)
= 0.220 Imperial gal-	= 3.785 liters
lon	= 4 quarts = 8 pints
= 1000 milliliters	= 128 fluid ounces
1 hectoliter (hl.) = 2.838	1 Imperial gallon (gal.)
bushels	= 4.546 liters
= 100 liters	= 1.201 U. S. gallons
= 0.1 cubic	1 bushel (bu.)
meter	= 0.3524 hectoliter
	= 2150.4 cubic inches
	= 1.2444 cubic feet
	= 0.03524 cubic meter

Volume

1 cubic centimeter (cc.)	1 cubic inch (cu. in.)
= 0.061 cubic inches	= 16.387 cubic centimeters
= 1000 cubic millimeters	1 cubic foot (cu. ft.)
1 cubic meter (cu. m.)	= 0.0283 cubic meter
= 35.314 cubic feet	= 1728 cubic inches
= 264.17 U. S. gallons	= 7.481 U. S. gallons

Volume (cont'd)

1 cubic meter (<i>cont'd</i>)	1 cubic foot (<i>cont'd</i>)
= 28.38 U. S. bushels	= 28.316 liters
= 1.308 cubic yards	1 cubic yard (cu. yd.)
	= 0.7646 cubic meter
	= 27 cubic feet

Field

1 kilogram per hectare (kg./ha.)	1 pound per acre (lb./A.) =
= 0.89 pound-per acre	1.121 kilograms per hectare
1 hectoliter per hectare (hl./ha.)	1 bushel (60 lb.) per acre (bu./
= 1.1484 bushels (60 lb.) per	A.) = 0.871 hectoliter per hec-
acre	tare = 67.26 kilograms per
1 quintal per hectare (q./ha. or	hectare
100 kg./ha.) = 1.4869 bushels	1 ton (short) per acre (ton/A.)
(60 lb.) per acre	= 2.242 metric tons per hec-
1 metric ton per hectare (m. ton/	tare
ha.) = 0.446 ton (short) per	
acre	

Pressure

1 atmosphere (atm.)	1 pound per square inch (lb./
= 14.696 pounds per square	sq. in. or psi.) = 70.307 grams
inch	per square centimeter
= 760 mm. of mercury (0°C.)	= 703.07 kilograms per square
= 1036 cm. of water	meter
1 gram per square centimeter	1 pound per square foot (lb./sq.
(g./sq. cm.) = 0.4912 pound	ft.) = 0.48824 gram per square
per square inch	centimeter
1 kilogram per square meter	= 4.8824 kilograms per square
(kg./sq. m.) = 0.20482 pound	meter
per square foot	
= 0.0014223 pound per square	
inch	



Acknowledgments

The writers wish to acknowledge most gratefully the generous assistance of numerous individuals, institutions, agencies, and publishers during the preparation of this book. Particular thanks are extended to the following:

Dr. Dean Akenhead, Director, Commonwealth Bureau of Horticultural and Plantation Crops, East Malling, England, for assistance in many ways.

Dr. R. V. Allison, Everglades Experiment Station, Belle Glade, Florida, for corrections and additions to the chapter on fiber crops, particularly ramie, kenaf, and sansevieria; and Dr. V. E. Green, Jr., for corrections and additions to the articles on cotton, rice, maize, sorghum, and tobacco, especially for the sections on culture, weed control, and steps to increase world production in rice, progress in maize improvement, recent advances in sorghum improvement, and cultural practices in relation to disease and nematode control in tobacco.

Dr. C. A. Black, Iowa State College, Ames, Iowa, for permission to reproduce the table on soil separates.

Mrs. Louise O. Bercaw, United States Department of Agriculture Library, Washington, D. C., for assistance with references.

Dr. A. F. Camp, formerly of the Citrus Experiment Station, Lake Alfred, Florida, for photographs of citrus.

Dr. K. Ebes, Imperial College, Ibadan, Nigeria, for assistance with references.

Dr. J. van Emden, Instituut voor Plantenziektkundig Onderzoek, Wageningen, Netherlands, for assistance with references.

Mr. Robert C. Evans, Florida Citrus Commission, Lakeland, Florida, for photographs of citrus.

Dr. Elise van Hall, Amsterdam, Netherlands, for permission to reproduce the illustration on fermentation boxes in *Cacao*, by C. J. J. van Hall. Copyright 1932. Macmillan & Company, Ltd., London.

Dr. Luther C. Hammond, University of Florida, Gainesville, Florida, for permission to reproduce the table on instruments for measuring soil moisture; and Drs. L. W. Ziegler and H. S. Wolfe for criticisms of the article on citrus.

Dr. C. W. S. Hartley, Director, West African Institute for Oil Palm Research, near Benin City, Nigeria, for information on oil palm.

Dr. W. C. van Heusden, Proefstation West Java, Bogor, Indonesia, for assistance with references.

Drs. Ernest P. Imle, Robert E. Adcock, and Carl V. Feaster and Mr. Charles T. Myers, Jr., United States Department of Agriculture, Beltsville, Maryland, for photographs of date, coffee, cacao, tea, rubber, olive, sesame, cotton, abaca, rice, sorghum, and tobacco, and information on various crops; Dr. P. W. Oman for correction of the check lists of insects; and Dr. John A. Stevenson for correction of the check lists of diseases.

Dr. M. L. Jackson, University of Wisconsin, Madison, Wisconsin, for permission to quote from *Soil Analysis—Chemical and Physico-chemical Methods*, 1950, on page 134 and to review a passage from the same source in Chapter 3; and Dr. E. Truog for permission to reproduce the illustration on the general trend of a soil's reaction (pH) and associated factors to the availability of its plant nutrient elements.

Dr. John L. Malcolm, Sub-Tropical Experiment Station, Homestead, Florida, for criticism of the several chapters on climate and soils; and Dr. George D. Ruehle and the late Dr. R. Bruce Ledin and Mr. John C. Noonan for information on a number of fruit crops and photographs of ilama and jaboticaba.

The late Mr. John Nicol and other members of the West African Research Institute, Tafo, Ghana, for information on cacao, especially diseases, and the photograph of black pod disease.

Mr. Robert E. Norris, Lake County Agricultural Agent, Tavares, Florida, for photographs of citrus grove operations.

Dr. W. V. D. Pieris, Office of the Director of Coconut Operations, Trust Territory of the Pacific Islands, Ponape, Eastern Caroline Islands, for review and criticism of the article on coconut.

Dr. P. Prevot, Directeur des Recherches de l'Institut pour les Huiles et Oléagineux, Paris, France, for information on coconut and oil palm.

Mr. Zach Savage, Agricultural Experiment Station, Gainesville, Florida, for data on costs of production of citrus.

Dr. C. A. Schroeder, University of California at Los Angeles, Los Angeles, California, for criticisms and corrections to the articles on fig, date, and olive.

Dr. H. F. Strohecker, University of Miami, Coral Gables, Florida, for correction of check lists of insects.

American Can Company, New York, N. Y., especially Mrs. Edalene Stohr, Home Economics Department, for permission to redraw the illustration of a Smooth Cayenne pineapple fruit.

Centrale Proefstations Vereeniging, Djakarta, Indonesia, for assistance in numerous ways, especially for permission to quote or otherwise utilize material from the publications under their control.

Cocoa Board, Department of Agriculture for Trinidad and Tobago, Port of Spain, Trinidad, B. W. I., for permission to quote from their publications and to use the illustrations of cacao replanting schemes.

Coconut Research Institute of Ceylon, Bandirippuwas Estate, Lunuwila, Ceylon, for permission to review their publications and to reproduce the illustrations of the Ceylon barbecue pit and kiln for copra.

Federacion Nacional de Cafeteras de Colombia, Chinchina (Caldas), Colombia, for permission to use the table on runoff and soil erosion.

Florida Agricultural Extension Service, Gainesville, Florida, for photographs of citrus, peanuts, tung, maize, and tobacco.

Florida Department of Agriculture, Tallahassee, Florida, for permission to redraw the illustrations of budding of citrus.

Food and Agriculture Organization of the United Nations, Rome, Italy, for permission to use data from their Yearbooks of Food and Agricultural Statistics on world production of major fruits, bananas, citrus fruits, figs, coffee, cacao, tea, natural rubber, major oil seeds, oil nuts and oils, copra, soybeans, peanuts, olives and olive oil, sesame seeds, tung, major natural fibers, cotton lint, cottonseed, kenaf (in jute), jute, hemp fiber, abaca (in hard fibers), hard fibers, sugar cane, rice, maize, sorghum, and tobacco.

Koninklijk Instituut voor de Tropen (Royal Institute for the Tropics), Amsterdam, Netherlands, for permission to reproduce illustrations on erosion dike-silt pit system, cultivation of pepper,

robusta coffee, tea estate, interior of a tea factory, seeds of hevea clones, clonal hevea plantation, Ledger cinchona, coconut plantation, kapok trees, cantala, and field of POJ 2878 sugar cane, and to adapt the drawing of floral biology of hevea.

Imperial College of Tropical Agriculture, St. Augustine, Trinidad, B. W. I., for information on bananas, cacao, and other crops.

Inter-American Institute of Agricultural Sciences, Turrialba, Costa Rica, for information and assistance in many ways.

Institut des Fruits et Agrumes Coloniaux, Basse Terre, Guadeloupe, F. W. I., especially Dr. F. L. A. Charles, Supervisor Division II, for much helpful information on control of banana pests.

Institut National pour l'Étude Agronomique du Congo Belge, Brussels, Belgium, for information on oil palm.

J. Horace McFarland Company, Harrisburg, Pennsylvania, for permission to reproduce illustrations of a cotton field, Golden Cross Bantam maize, Sussex White dent maize, and heads of sorghum.

Texas Research Institute, Renner, Texas, for permission to reproduce illustrations of a sesame flower and stalks of sesame.

United Fruit Company, Publications Division, and Fruit Dispatch Company, New York, N. Y., for helpful information and assistance in many ways including permission to quote from *Chemical and Physical Changes in Bananas during Ripening and Their Relation to Flavor* and to reproduce illustrations on overhead irrigation, disinfecting of new banana "seeds," spraying of bananas, open areas in a plantation where Panama disease has killed plants, flood fallow lake, harvesting bananas, washing bananas, rail cars for hauling bananas, loading bananas, commercial grades and stages of ripening of bananas, Colombian, Costa Rican, and Guatemalan systems of training coffee, propagation bins for cacao cuttings, harvesting cacao, young oil palms, packing young oil palms for transplanting, bearing oil palm, and sterilizing oil palm fruits.

United States Information Service, Colombo, Ceylon, for photographs of a field of jute and separating and washing jute fibers.

For permission to quote and to use tables and illustrations from other publications, the writers wish to express their gratitude to the following publishers, who have generously granted these rights:

Academic Press, Inc., New York, N. Y., for quotations, tables, and illustrations from *Soil Physical Conditions and Plant Growth*, B. T. Shaw, editor, *Agronomy*, Monograph Series, Vol. II, 1952; L. T.

Alexander, "The Physical Nature of Soil" on pages 142, 154, 155, and 156; L. A. Richards and C. H. Wadleigh, "Soil Water and Plant Growth" on pages 146 and 151 (adapted); from *Fertilizer Technology and Resources in the United States*, K. D. Jacob, editor, *Agronomy*, Monograph Series, Vol. III, 1953, on pages 219-222; from *Soil and Fertilizer Phosphorus in Crop Nutrition*, W. H. Pierre and A. G. Norman, editors, *Agronomy*, Monograph Series, Vol. IV, 1954, on pages 219-222; from *Corn and Corn Improvement*, G. F. Sprague, editor, *Agronomy*, Monograph Series, Vol. V, 1955: R. H. Shaw, "Climatic Requirement" on page 1278; from *Advances in Agronomy*, Vol. 5, 1953: M. L. Jackson and G. D. Sherman, "Chemical Weathering of Minerals in Soils" on pages 64, 65, 66, and 113; and for review of passages from C. E. Marshall, *The Colloid Chemistry of the Silicate Minerals*, *Agronomy*, Monograph Series, Vol. I, 1949, in Chapter 3; from *Soil Physical Conditions and Plant Growth*, B. T. Shaw, editor, *Agronomy*, Monograph Series, Vol. II, 1952: L. A. Richards and C. H. Wadleigh, "Soil Water and Plant Growth"; M. B. Russell, "Soil Aeration and Plant Growth"; and S. J. Richards. R. M. Hagan, and T. M. McCalla, "Soil Temperature and Plant Growth" in Chapter 3; from *Advances in Agronomy*, Vol. I, 1949: J. E. Gieseking, "The Clay Minerals in Soils" in Chapter 3; and L. A. Dean, "Fixation of Soil Phosphorus" and K. C. Berger, "Boron in Soils and Crops" in Chapter 4; from *Advances in Agronomy*, Vol. 2, 1950: E. C. Childs and N. Collis-George, "The Control of Soil Water" in Chapter 3; from *Advances in Agronomy*, Vol. 3, 1951: L. E. Ensminger and R. W. Pearson, "Soil Nitrogen" in Chapter 3; from *Advances in Agronomy*, Vol. 4, 1952: F. A. Gilbert, "Copper in Nutrition"; E. G. Mulder and F. C. Gerretson, "Soil Manganese in Relation to Plant Growth"; and N. E. Tolbert and P. B. Pearson, "Atomic Energy and the Plant Sciences" in Chapter 4; from *Advances in Agronomy*, Vol. 5, 1953: F. E. Broadbent, "The Soil Organic Fraction" in Chapter 3; from *Advances in Agronomy*, Vol. 6, 1954: O. J. Kelley, "Requirement and Availability of Soil Water" in Chapter 3; K. Lawton and R. L. Cook, "Potassium in Plant Nutrition" in Chapter 4; A. A. Nitikin, "Technological Aspects of Trace Element Usage" in Chapter 4; and J. R. Quinby and J. H. Martin, "Sorghum Improvement" in Chapter 14; from *Advances in Agronomy*, Vol. 7, 1955: F. E. Allison, "The Enigma of Soil Nitrogen Balance Sheets"; C. H. Wadleigh, "Mineral Nutrition of Plants as Related to Microbial Activities in Soils"; and G. W. Harmsen and D. A. van

Schreven, "Mineralization of Organic Nitrogen in Soil" in Chapter 3; J. Bonner, *Plant Biochemistry*, 1950, and *Advances in Agronomy*, Vol. 5, 1953; M. L. Jackson and G. D. Sherman, "Chemical Weathering of Minerals in Soils" were used along with other sources in compiling Table 34.

American Genetic Association, Washington, D. C., for quotations and use of illustrations from *Journal of Heredity*, 1921: W. Popenoe and O. Jiminez, "The Pejibaye—a Neglected Food-Plant of Tropical America" on pages 694–696 and 697.

American Soybean Association, Hudson, Iowa, for illustrations of soybeans from *Soybean Digest*, 1953, on pages 1067 and 1070.

Cadbury Brothers, Ltd., Bourneville, England, for colored illustrations from *Internal Characteristics of Cacao Beans*, n.d., following page 852.

Centrale Proefstations Vereeniging, Djakarta, Indonesia, for material from A. F. Schoorel, *Handleiding voor de Theecultuur*, 1949, on pages 254, 260, 882, 884, 885, 890, 895, and 897.

Chemical Rubber Publishing Company, Cleveland, Ohio, for physical constants of major alkaloids in cinchona bark compiled from *Handbook of Chemistry and Physics*, 26th ed., edited by C. D. Hodgeman and H. N. Holmes, 1942, on page 1015.

The Clarendon Press, Oxford, England, for tables from A. F. W. Schimper, *Plant Geography upon a Physiological Basis*, 1903, on pages 6 and 23.

Djawatan Perlengkapan dan Bangunan, Kementerian P. P. K. of the Republic of Indonesia, Djakarta, Indonesia, for illustrations from J. J. Ochse, *Indische Vruchten*, 1927, on pages 490, 491, 526, 531, 547, 559, 560, 564, 569, 581, 588, 596, 600, 605, 607, 611, 616, 619, 645, 650, 653, 656, 670, 672, 674, 675, 677, 680, 683, 687, 691, 693, 705, 710, 713, 714, 718, 722, 725, 727, 731, 736, 739, 745, 748, and 770.

General Foods Corporation, Walter Baker Division, Brooklyn, N. Y., for table from *Educational Exhibit of Cacao and Chocolate*, n.d., on page 855.

Walter de Gruyter and Company, Berlin, Germany, for table from W. Köppen, *Die Klima der Erde*, 1923, on page 35.

Hawaiian Sugar Planters Association, Honolulu, T. H., for illustration from J. P. Martin, *Sugar Cane Diseases in Hawaii*, 1938, on page 1207.

N. V. Uitgeverij W. van Hoeve, s'Gravenhage, Netherlands, for tables, quotations, and illustrations from E. C. J. Mohr and F. A.

van Baren, *Tropical Soils*, 1954, on pages 12, 13, 14, 17, 47, 48, 49, 50-51, 52-53, 54, 56, 58, 60, 61, 62, 63, 70, 71, 72, 74, 76-77, 78-81 (adapted), 82-83 (adapted), 85 (adapted), 86 (adapted), 90, 91, 95, and 141; from *De Landouw in de Indische Archipel*, C. J. J. van Hall en C. van de Koppel, editors: Deel I, 1946: J. G. Ossewaarde and S. J. Wellensiek, "Capita Selecta uit de Algemeene Plantenteelt" on pages 238, 252, 258, and 281; Deel II A, 1948: C. Braak, "Klimaat" on pages 9, 10, and 11 and V. J. Koningsberger, "De Europeesche Suikerrietcultuur en Suikerfabricage" on page 1205; and Deel III, 1950: J. G. J. A. Maas and F. T. Bokma, "Rubbercultuur der Ondernemingen" on pages 935 (adapted), 950 (adapted), 970 (adapted), and 979, 987, and 988; and for review of passages from E. C. J. Mohr and F. A. van Baren, *Tropical Soils*, 1954, in Chapters 1, 2, and 3.

Kementarian Pertanian of the Republic of Indonesia, Djakarta, Indonesia (Pusat Djawatan Pertanian Rakjat), for botanical descriptions adapted from J. J. Ochse (in collaboration with R. C. Bakhuizen van den Brink), *Vegetables of the Dutch East Indies* (English edition of *Indische Groenten*), 1931, on pages 524, 648-649, 744, 746, 763, 775, 930-931, 1034-1035, 1068-1069, 1077-1078, 1090-1091, 1133-1134, 1148-1150, 1173-1174, and 1270-1271.

G. Kolff and Company, Djakarta, Indonesia, for a quotation and botanical descriptions adapted from J. J. Ochse (in collaboration with R. C. Bakhuizen van den Brink), *Fruits and Fruit Culture of the Dutch East Indies* (English edition of *Vruchten en Vruchten-teelt in Nederlandsch-Oost-Indië*), 1931, on pages 375, 482-483, 487-488, 495-496, 500-501, 505-506, 526, 527-528, 546, 548, 549-550, 558-560, 561-562, 563-565, 570-571, 587-589, 596-597, 600-601, 605-606, 612-613, 622-623, 644-646, 649-651, 653-654, 673, 675-676, 678, 679-681, 687-688, 690-692, 706-707, 709-711, 714-716, 719-720, 732-734, 735-737, 740, and 741.

Leonard Hill (Books) Ltd., London, England, for quotations from A. E. Haarer, *Modern Coffee Production*, 1956, on pages 785-786, 788, 791, and 792; Sir E. J. Russell, *Soil Conditions and Plant Growth*, 8th edition, revised by E. W. Russell, 1950, on pages 118-119, 122, 126, 132, and 157; and D. H. Urquhart, *Cocoa*, 1955, on page 857; and for review of passages from *Modern Coffee Production* in the article on coffee in Chapter 10; and from *Soil Conditions and Plant Growth*, 8th edition, in Chapter 3.

The Macmillan Company, New York, N. Y., for quotations, table,

and adapted botanical descriptions from L. H. Bailey, *The Standard Cyclopedia of Horticulture*, 1928, on pages 375, 376, 558, 614-615, 1077-1078, 1083-1084, 1177-1178, 1180, 1182, 1183, and 1184-1185; from L. H. Bailey, *Manual of Cultivated Plants*, revised edition, 1949, on pages 376-377, 552, 557, 699, 712-713, 767, 1050, 1077-1078, 1083-1084, 1118-1122, 1140-1141, 1166-1167, 1253-1254, 1274-1276, 1287-1288, 1289-1290, and 1299; from K. H. W. Klages, *Ecological Crop Geography*, 1942, on pages 26-27, 36-37, 38, and 40; from T. L. Lyon and H. O. Buckman, *The Nature and Properties of Soils*, 4th edition, 1946, on pages 44 and 164-165; from J. H. Martin and W. H. Leonard, *Principles of Field Crop Production*, 1950, on page 1291; and for review of passages from *Ecological Crop Geography*, in Chapter 1; and data from W. Popenoe, *Manual of Tropical and Subtropical Fruits*, 1920, used in compiling Tables 59, 60, and 62.

Macmillan and Company, Ltd., London, England, for an illustration and tables from C. J. J. van Hall, *Cacao*, 1932, on page 851; and from P. Vageler, *An Introduction to Tropical Soils*, 1933, on pages 109, 110, and 194.

National Research Council, Washington, D. C., for a table from M. C. Kik and R. R. Williams, *The Nutritional Improvement of White Rice*, National Research Council Bulletin 112, 1945, on page 1263.

Oxford University Press, London, England, for a quotation from J. K. Matheson and E. W. Bovill, *East African Agriculture*, 1950, on page 1176.

Pan-American Union, Washington, D. C., for a table from W. Popenoe, *Cultivo del Banano en la Zona del Caribe*, Union Pan-americana, Serie de Agricultura No. 113 y 114, 1936, on page 384.

Charles Scribner's Sons, New York, N. Y., for a quotation from David Fairchild, *The World Was My Garden*, 1938, on page 615.

Staples Press, London, England, for a table from H. C. Sampson, *The Coconut Palm*, 1923, on page 196.

H. D. Tjeenk Willink en Zoons, Haarlem, Netherlands, for illustrations from S. J. Wellensiek, *Grondslagen der Algemeene Plantenveredeling*, 1947, on pages 336, 337, 339, 340, 341, 343, and 875.

University of California Press, Berkeley, California, for tables and passages adapted from *The Citrus Industry*: Vol. I, H. J. Webber and L. D. Batchelor, editors, 1943: W. T. Swingle, "The