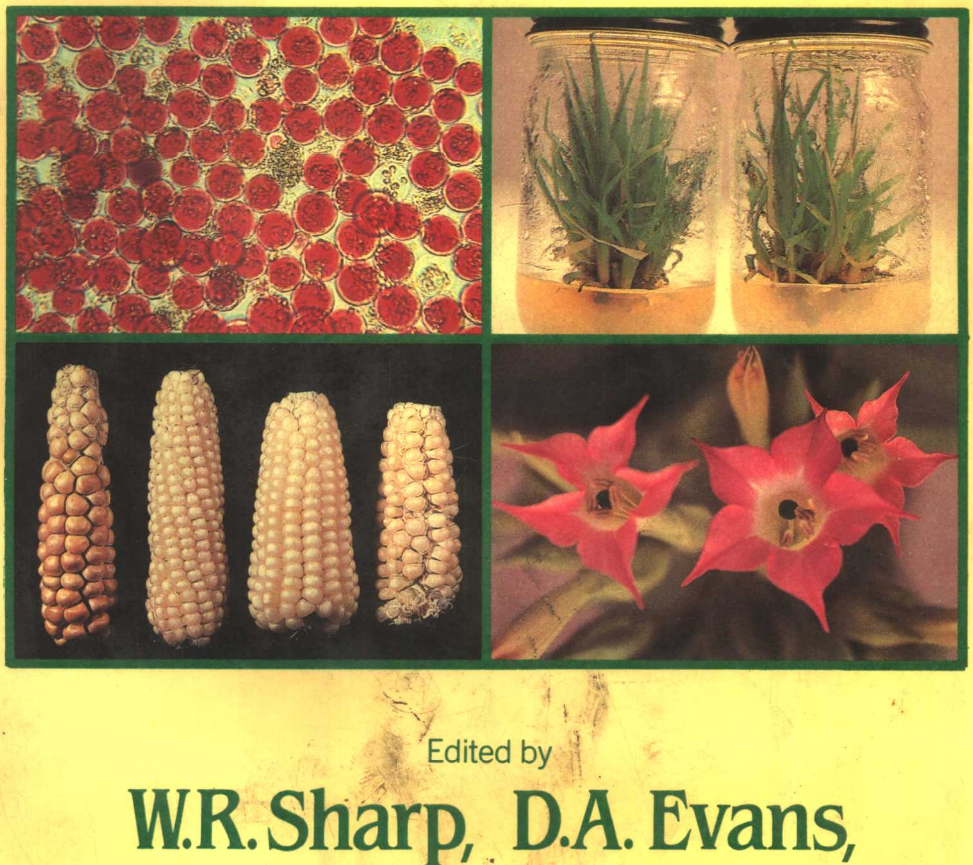
HANDBOOK of PLANT CELL CULTURE

VOLUME 2

Crop Species



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HANDBOOK OF PLANT CELL CULTURE, Volume 2

Crop Species

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HANDBOOK OF PLANT CELL CULTURE

Volume 2

Crop Species

This second volume in a new multi-volume treatise applies the state-of-the-art plant cell culture techniques described in Volume 1 to a wide range of crops. In 21 authoritative chapters, the world's foremost scientists cover maize, oats, wheat, beans, red clover and other forage legumes, asparagus, celery, cassava, sweet potato, banana, papaya, apple, grapes, conifers, date palm, rubber, sugarcane, and tobacco.

As in Volume 1, the contributors emphasize practical methodology. Every chapter contains 1) detailed protocols which serve as the foundation for current research; 2) a critical review of the literature, including key contributions and summary tables that highlight valuable information; and 3) in-depth evaluations of the tremendous potential this field shows for crop improvement. In addition, the history and economic importance of each crop is discussed. This standard format ensures a clear and continuous presentation.

Special features include an informative essay by Nobel Prize-winner Melvin Calvin on the potential use of plants as a direct source of oil and other hydrocarbons and introductory chapters that concisely summarize major food and energy crops and general methods for their improvement. The definitive reference work on applying specific cell culture techniques to major crops, this volume is an

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indispensable source of information for plant scientists and students as well as researchers in agronomy, horticulture, phytopathology, molecular biology, and plant biology.

About the editors

WILLIAM R. SHARP, formerly Professor of Microbiology at Ohio State University, and **DAVID A. EVANS**, formerly of SUNY Binghamton, are the cofounders of the DNA Plant Technology Corporation, a leader in the development of new crops through bioengineering, based in Cinnaminson, New Jersey. **PHILIP V. AMMIRATO** is Chairman of the Biology Department at Barnard College, Columbia University, and **YASUYUKI YAMADA** is Professor of the Research Center for Cell and Tissue Culture, Faculty of Agriculture, Kyoto University, Japan.

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Preface

The tools of plant cell culture are increasingly being applied to a wide range of biotechnology ventures and in particular to the propagation and genetic improvement of crop plants. For this, the approaches and methodologies must be specifically adapted to the differing problems and potentialities of each crop and to the differing responses of plants that may be herbaceous or woody, dicotyledonous or monocotyledonous, annual or perennial, inbred or highly heterozygous. It is the application of plant cell culture techniques to the improvement of specific crop plants that is the subject of Volumes 2 and 3 of this series.

The list of plants that play an important part in agribusiness is longer than one might initially surmise. The selection of those to be included in these volumes reflects a necessary amalgam of several factors—the plants chosen must be of recognized economic importance, they need to have been successfully employed in cell culture research, and a key investigator had to be available and willing to contribute. Some important crops, then, are not here because these elements did not come together. And it is to be expected in any area where technology is only just being applied that there will be varying degrees of experience and success. This can be seen in the varying lengths of the presentations. The plants finally selected do represent major crops where cell culture methodology has been demonstrably applied.

In addition, in each volume, several general chapters provide overviews of topics that are particularly relevant to the subject at hand. In this volume, we have included a discussion of major food and energy crops, their relative economic importance, trends in production and trade, and indications of looming problems, including a potential diminution of food supplies with an increasing shift to energy crops. A second chapter summarizes current cell culture methods available for crop improvement and sets the stage for the subsequent discussions of individual crop plants. The reader is directed to Volume 1 in this series for a detailed exposition of these techniques.

As in our first volume, we are pleased to have an introductory essay by a distinguished scientist. Melvin Calvin, Nobel Prize recipient for his work in the elucidation of the path of carbon assimilation in photosynthesis, discusses the potential use of plants as a direct source of oil and other hydrocarbons. His search for plants that can grow on land not used for food production is particularly important.

The centerpiece of this volume, as for the entire series, is practical methodology, and we have again included for each chapter a major section with acutal protocols, whether as recipes, tables, charts, or narratives. To introduce the specific crop, the history and economic importance are presented, culminating in a discussion of important breeding and propagation problems, areas in which cell culture methods may be particularly applied. A critical review of the literature summarizes past and current cell culture work, and a discussion of future prospects details where we may expect the technology to go. Again, key references have been highlighted and references are given with full citation.

As before, our goal is to provide a comprehensive and practical compilation that students and scientists, academicians and businessmen alike will find informative and useful in both understanding current strategies and in extending scientific frontiers.

We are indebted to our editors at Macmillan, Sarah Greene and Frances Tindall, for the necessary support in bridging the gap from concept to book. Janis Bravo again served as editorial assistant, the crucial link from us to both authors and editors and for which she deserves our sincere appreciation. Lastly, we offer our deep thanks to our many authors who provided manuscripts on time and ushered them through the various publication stages with despatch and good cheer.

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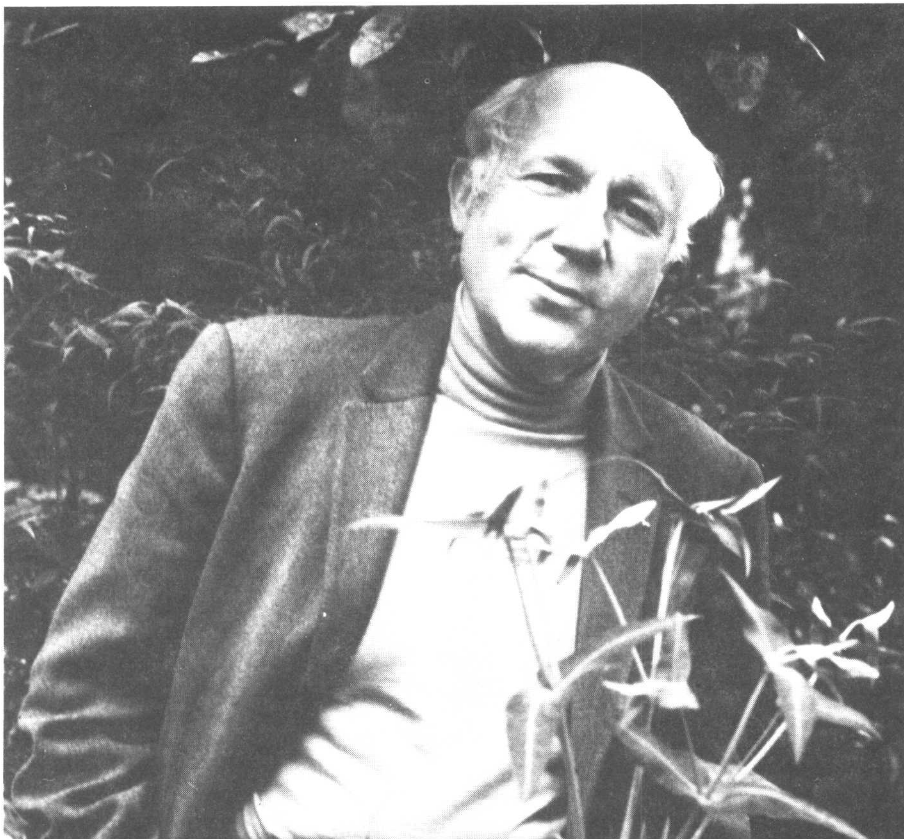
"It's a genetic engineer. He wants to know if he can patent designer beans."



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SPECIAL ESSAY:

Oil from Plants

M. Calvin

Growing oil, my subject for this essay, means just that. Up until now, we have been mining oil, the photosynthetic product of several hundred million years ago. The question now frequently arises about new sources of ancient photosynthetically produced materials, and there is no longer a tenable positive answer. Alternatives to mining oil must be found.

An immediate need for alternate energy sources is emphasized by the history of productivity of drilling rates for United States domestic petroleum from 1945 to the present time. It has been demonstrated that the amount of oil found per foot of well drilled is falling, from 35 barrels in 1945 to less than half that amount in 1975. Also, the rate of discovery is falling, and the energy cost of drilling and extracting oil is rising (Hall and Cleveland, 1981). Somewhere near the year 2000 the energy cost of finding and extracting a barrel of oil will exceed the energy content of that barrel of oil.

CARBON DIOXIDE PROBLEM

One alternative to oil that has been suggested is coal (also a product of ancient photosynthesis), huge supplies of which are available in the United States, the Soviet Union, Europe, and China, but this also has some problems. About 20-30 years ago we were admonished to restrict the use of coal because of environmental problems such as the destruction of land by strip mining, hazards to miners, and dangers posed by such effluents of burning coal as acid rain and carcinogenic hydrocarbons. We transformed our coal burning power plants into clean (gas) or low sulfur (oil) burning power plants to eliminate or reduce environmental hazards. As a result of the oil embargo in 1973, there has been a return to the use of coal for power plants, especially by indirect combustion (coal conversion to gas or liquid hydrocarbons) rather than by older combustion methods. When we suggest that coal in any form can be used as an alternative to burning oil, it should be remembered that environmental constraints will prevent its use over an extended period.

The combustion of fossil carbon in any form, but particularly coal, has created a problem, especially over the last 100 years and in an accelerated form in the last 20 years. Carbon that has been stored in the ground for several hundred million years and is suddenly used generates excess carbon dioxide. It is not possible to get the heat/energy values from the combustion of fossil carbon (oil or coal) without the production of CO_2. As a result, there has been a 7% increase in atmospheric CO_2 levels over the past 20 years, even from burning mostly oil, which has approximately two atoms of hydrogen for every atom of carbon. When coal is burned, however, there is less than one atom of hydrogen for one atom of carbon, with the result that roughly twice as much carbon dioxide per million BTUs is created than from the burning of oil.

It is possible to observe the annual increase in the CO_2 levels in the atmosphere from the data in Fig. 1, which is taken from a station at the top of Mauna Loa in Hawaii. This site was chosen because of

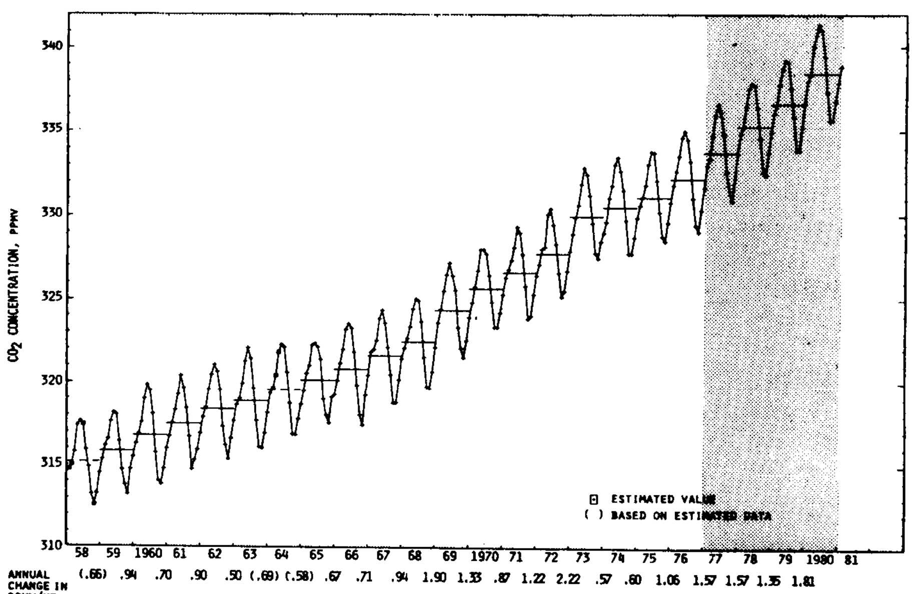

Figure 1. CO_2 concentration at Mauna Loa, Hawaii (data from C.D. Keeling et al., Scripps Institution of Oceanography).

its distance from urban and natural disturbances, so that the data obtained is representative of the actual atmospheric situation uncontaminated by manmade pollutants. The annual changes of the CO_2 levels in the atmosphere are clearly observable, with a rise in the winter and drop in the summer. Notice that the reduction in the summer is never as great as the increased concentration in the winter, resulting in a constant net CO_2 increase since 1958, from 315 to over 330 ppm.

We can actually extrapolate backward by another type of measurement, the ^{13}C content of tree rings that were laid down in 1860. From the ^{13}C deficiency we can estimate the total carbon dioxide that was in the atmosphere in 1860; it turns out to be about 290 ppm for that time. So, from 1860 to 1980 there has been an increase of about 15% atmospheric CO_2, and of that amount, half has been in the period 1958-1981. There has been a slight decrease in worldwide carbon-based fuel usage since the oil embargo period, but that is a relatively small perturbation on the overall rise of the CO_2 concentration.

Why is the CO_2 level important? Carbon dioxide is a peculiar gas. It is transparent to visible light. Approximately 99% of visible light is converted to heat when it strikes the surface of the earth after passing through the atmospheric CO_2 blanket. This heat is irradiated back into space, but the carbon dioxide is opaque to infrared light and absorbs it, re-reflecting some of it back down to the earth's surface. The CO_2 blanket thus acts as a one-way valve, letting heat into the surface of the earth but not allowing the heat to escape again into space, with a result that the earth's surface temperature rises (Smagorinsky, 1982; Macdonald, 1982).

Effect of Rising World Temperature

Let's discuss for a moment what the rising temperature of the earth may be expected to be and what the possible economic and social costs might be as a result. Estimates have been made by various means and the data show rising temperatures as a result of synthetic fuel use might be as great as 4 C, a very large change in the average global temperature of today. Even if we begin to use nonfossil replacement fuels, we still have the inertia of the CO_2 rise that has already begun and will continue. There is no way to stop the temperature rise that has already begun, and it will take 50-100 years before the increase levels off or even begins to fall again. We can be sure that if such temperature rises take place, there will be profound effects on agriculture, on human distribution, and on human societies that will have to adjust to a relatively very rapid change.

Several years ago the National Academy of Sciences organized a study on the effects of the increased CO_2 concentration in the atmosphere, and in 1982 they updated their findings (Smagorinsky, 1982). The 1982 report stated that the increase in temperature of 3 C postulated in 1979, which was predicted to accompany a doubling of atmospheric CO_2 concentration, needs "no substantial revision" at this time. The potential of increasing concentrations of atmospheric CO_2 to