most diseases. Such diseased plants should be discarded and only those free of disease should be used for propagation of plants.

MODERATOR MAIRE: Thank you, Dr. Raabe. We will now continue with our discussion of this subject with a talk by Dr. Stephen Wilhelm and Dr. Arthur McCain on how to produce clean propagating materials.

PRACTICAL TECHNIQUES FOR THE PRODUCTION OF CLEAN PROPAGATING MATERIALS

STEPHEN WILHELM
Department of Plant Pathology
University of California, Berkeley

Practical techniques for the production of clean propagating materials involve three basic operations, and these lie at the heart of the subject matter of the fields of plant pathology and horticulture. The raising of superior plants through advances in horticultural science and the control of plant disease are our common objectives and no longer should anyone just assume that plant diseases are inevitable and crop losses to be expected. The three basic operations referred to above are: (1) getting rid of the pathogen at the source (2) getting rid of pathogen carry-over in the soil or from other growing or propagating media (3) getting rid of all sources of contamination by which the pathogen can be reintroduced into growing operations. The first operation — getting rid of the pathogen at the source — means obtaining pathogen-free planting stock, and the full meaning of "clean stock" as used in this talk is stock that is not carrying any known injurious organisms, fungi, bacteria, nematodes or viruses. The second operation — getting rid of pathogen carry-over in the growing media — involves methods of disinfecting, fumigating, or steaming, soils and other growing media, and for this subject matter area, I wish to direct your attention to University of California Manual 23, entitled the U. C. System for Producting Healthy Container-Grown Plants, Chapter 8-13 inclusive, edited by Dr. K. F. Baker. The third operation — getting rid of all sources of contamination — includes maintaining stocks pathogen-free by preventing the reintroduction of pathogens with tools, containers, tractors, water, worker, or insects, etc. This important subject matter area will be discussed by Dr. McCain, and in a practical way was illustrated by the high standards of hospital cleanliness depicted in the talk of Fred Real of the Four Winds Nurseries, San Jose.

Much of our past thinking in plant pathology, perhaps forced upon us by expediency and at the bottom, of our own wishes to serve agriculture, was to provide controls for plant diseases. This we have done, and recommendations involving plant sprays, dusts, drenches, with timing of application that coincides with vulnerable stages in the life cycles of the causal organisms, are readily available. Essential as these measures are to agriculture and horticulture, this approach to control by "fighting" the diseases never got us to the bottom of

disease problems. Also, working along the lines of control by "fighting" diseases only, tended to compartmentalize our own subject matter and we often looked at plant disease control as if it involved separate and distinct operations from those of growing the crop. The common question is "how do you control this or that disease?" In many instances we now know that if the disease, or properly speaking, the *causal agent or pathogen* of the disease were eliminated from the planting stock at the outset, "fighting" the disease becomes unnecessary. To effectively eliminate a disease at the outset may require considerable change in old esablished growing routines, and if this is so, only those who change reap the advantages available through plant disease control.

Only a relatively few years ago it was the established practice among San Francisco Bay Area chrysanthemum growers to take cuttings in the winter from the old, spent flower beds. Under pathogen-free conditions, there is nothing wrong with this practice, but studies showed that the following diseases: Verticillium wilt, Deuterophoma stunt, Rhizoctonia and Sclerotinia foot rots, Pythium and Pyrenochaeta root rots were carried latent with these healthy-looking cuttings. In addition, such cuttings also could carry two different kinds of serious nematode parasites, several kinds of leaf-infecting fungi and the debilitating virus disease called "stunt." Any one of these diseases *if serious enough, can stille successful chrysanthemum* production, and when propagative stock carries the disease-causing organisms, the chances for serious outbreaks are excellent. The reasons why chances for serious disease outbreaks are excellent if planting stock — no matter how healthy its appearance — is carrying pathogens, are these: (1) the causal organism and the crops are transported and planted simultaneously (2) the causal organism is either already in the planting stock or closely associated with susceptible tissues and (3) the particular strain of the pathogen virulent for the crop is the one being spread. Thus, to get back to the Verticillium wilt disease of chrysanthemum, the causal fungus is within the cutting and the strain of the fungus spread by the cutting is the one virulent for chrysanthemum. There are many strains of this fungus and on land never previously planted to chrysanthemum, for instance, such as old brussel sprout land, you may encounter heavy infestations of Verticillium but the particular strains may not attack chrysanthemums. If infected cuttings, however, are planted on this land, outbreaks of the disease are assured.

Thus far we have presented the principles involved in disease control by planting only clean (pathogen-free) stock. Now, how do we go about obtaining such clean stock? The first requirement is separation of planting stock production from crop production. Whether the crop is fruit, shrubs, flower seed, or bulbs, the plant propagative and crop productive operations which in themselves are distinct, must be separated. You nurserymen may tell me, and correctly so, that plant nurseries existed long before even the science of plant pathology and that thus intuitively long ago this separation of operations was made. Separation today, however, means more than just producing

planting stocks in the nursery, because nurserymen have been known to depend often on commercial growers for seed, budwood, scions, for land and equipment. Verticillium wilt of rose, a fungus disease, for instance, can be transmitted through bud wood, as well as can the *Coniothyrium fungus by budding, as of course, can all of the virus* diseases. Where insects that spread diseases such as virus disease may be involved, the idea of separation may mean many miles of isolation of nurseries from the crop-producing areas, and even mechanical barriers such as screen houses and disinfecting troughs for workmen's shoes. In the strawberry industry, with which I am most familiar, the nurseries are some hundreds of miles from the production areas, and foundation stocks there are often kept in isolation in screen houses. No strawberry grower any longer would think of stripping old commercial fields for runner plants to obtain stock for planting new fields.

The nurseryman has a responsibility, often deeper than moral, to supply the growers with clean stock, but unless his stocks are clean to begin with, his propagation techniques carry infections with them. Though some progress has been made in methods of mass cleaning up of diseased planting stocks, especially by use of hot water, generally it cannot be done. It is better to spend a lot of time and care on a few selected individuals that have been ridded of pathogens, and *tested out as "pathogen-free" and to propagate only from them.* Three basic methods are used today to rid planting stocks from infestations, but by no means have the practical potentials of these methods been fully explored. These methods are *heat treatments, culturing cuttings,* and *apical meristem cultures.*

Heat Treatments

Heat treatment of plant materials to control diseases is one of the oldest methods of disease control. Dr. K. F. Baker, Dept. of Plant Pathology at UCLA, who is a foremost authority on this subject, has estimated that annually about 75,000 tons of sugar cane planting stock are treated to control virus diseases in Hawaii, 15,000 tons in Australia, 15,000 tons in Louisiana. About 1,000 tons of narcissus bulbs are treated annually in Washington against nematodes and anywhere from 500,000 to 1,000,000 strawberry plants treated annually *in California.*

Living organisms vary widely in their tolerance of high temperatures. Most parasitic fungi for instance, are killed by moist heat, which includes hot water, in 30 minutes at 120 to 135° F. Though many dormant seeds and other propagules, such as bulbs and corms, will tolerate this heat, most actively-growing shoots and twigs will not. Actually, the higher the moisture content of plant materials or of organisms, the greater the susceptibility to destruction by heat.

A recent modification in the use of heat is to grow plants at temperatures of 100 to 105° F. for periods of 2 to 30 weeks. Several virus diseases of strawberry, raspberry, rose, and stone fruits, have been eliminated in this way and basic stocks have been built up from these. Plants must be hardened before subjecting them to these high

temperatures, allowed to adjust to the temperatures gradually, and provided with high light intensities.

Culturing Cuttings

Over 20 years ago, Dr. W. Dimock, Professor of Plant Pathology, Cornell University, a foremost authority in diseases of ornamental plants, studying the Verticillium wilt disease of chrysanthemums showed that the infection does not reside in the tips of the cuttings. This important discovery has enabled informed nurserymen to specialize in the production of stocks whose parents have a "cultured" pedigree. This pedigree distinguishes them as pathogen-free. Yoder Brothers, Salinas, California, is such a nursery. The idea of detecting latent bacterial and fungal infections in tip cuttings, applied first practically to chrysanthemum, is now widely used in carnation and geranium propagation, and to a limited extent in rose. The details as to just how this culturing is done, which varies with both the crop and the pathogens involved, are available to anyone interested, but are too involved to discuss here.

Apical Meristem Cultures

A general principle which developed out of Dr. Dimock's idea of culturing chrysanthemum cuttings to detect Verticillium, is that *infections of all kinds, fungal, bacterial, viral, diminish and tend to peter out in* the direction of the growing tip of a shoot. By carefully dissecting out the actual growing tips (apical meristems) of some plants and growing them aseptically in a manner similar to the embryo culture techniques described yesterday by Dr. Lammerts, pathogen-free individuals have been obtained. Obviously, a highly specialized technique, and one not adapted to any kind of mass procedures, nevertheless important stocks of important crops have been ridded of *virus* infections in this way. Strawberry, potato, carnation, dahlia, and lily are a few. Frequently, techniques involve a combination of the use of heat and apical meristem culturing. Valuable stocks may be subjected first to long periods of high temperatures, during which they may make some growth. This growth, or the first to appear when the stocks are returned to normal temperatures, is used for the apical meristem cultures. Details as to just how the apical meristem culturing is done are also available but will not be considered here.

As Dr. W. Dimock has pointed out in his articles, an inevitable tendency that attends crop specialization is the concentration of propagation into ever fewer, and larger-scale propagators. Such specialization, though possessed of obvious economic advantages of production and distribution, holds the potential of either promoting horticultural uniformity and excellence or of spreading disease. Diseases developing in parent stocks of large propagators are speedily spread throughout the clientele and this may involve many of the growers of one or of several countries. On the other hand, elimination of diseases in the parent stocks of these same large propagators and by guarding against their ever reappearing, may eliminate or greatly reduce the disease problems for this same entire clientele.