acetic acid and/or a splitting of the experiment and placing part of the cultures in dark and part in light.

RECAP OF IMPORTANT CONSIDERATIONS

It is imperative that the instructor make sure that the exercise teaches a practice, skill or principle. It is also extremely important that the instructor know that the exercise work successfully The best way to know that, is to have practiced it oneself. Organizing the exercise well in advance of the implementation of the exercise by the students will also enable students to have a successful learning experience from these laboratory exercises. Finally, observations of results should be evaluated and discussed for maximum understanding of the value of these exercises.

Numerous other exercises such as scooping or scoring hyacinths, herbaceous cutting exercises, herbaceous grafting techniques and similar exercises could be handled in a manner similar to the three exercises discussed in this presentation. Such exercises can be developed by the instructor or they can be found in available laboratory manuals.

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ASPECTS OF A TEACHING PROGRAM FOR PLANT TISSUE CULTURE

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Tissue culturing of plants as a means of asexual propagation is an example of a tool which was developed and refined by the research community long before it gained acceptance as a technology for use in industry. This lack of concomitant development by industry and university researchers has led to communication gaps in the implementation of techniques and applications. Since most plant propagation teaching programs cover tissue culture briefly and from a theoretical perspective, most students are

unaware of the impact which the emerging tissue culture technology is having and will have on the business of plant propagation.

The Department of Horticulture at Ohio State University has begun a program to address the nursery industry's needs for individuals who have an appreciation for and some knowledge of the techniques of plant tissue culture as a propagation tool. This teaching program encompasses courses taught at several levels. Included in the program are Horticulture 415, the undergraduate plant propagation course, Horticulture 715, a graduate level course in techniques and applications of tissue culture, and, Horticulture 293, 593, and 993, which are undergraduate or graduate level and are taught as individual studies with special permission of the program coordinator.

Students in the plant propagation course, Horticulture 415, are exposed to only the basics of plant tissue culture. Since both lecture and laboratory time are extremely limited, a student could not be expected to do tissue culturing independently after only such a brief exposure to the methodology. Furthermore, the objective of teaching tissue culture as a part of the plant propagation course is to familiarize the student with the concept of tissue culture as a propagation tool rather than the specifics of the methods.

The fundamental principles which are emphasized in the teaching program at this level are extremely basic (Figs. 1-4). Factors to be considered when choosing a tissue source for the original explant are covered (Fig. 1). Anatomical and morphological changes accompanying the proliferation of multiple shoots from leaf tissue (Fig. 2) and from shoot tip explants (Fig. 3) are explained with liberal use of visual aids including actual cultured specimens. Perhaps the most attention is given to the presentation of the concept of subculturing (Fig. 4) since it is through this process that the extraordinarily high multiplication rates characteristic of tissue culture methods are achieved. To complete the teaching of the propagation cycle, methods for rooting of the cultured plantlets and the procedures used to acclimate the plantlets to the greenhouse environment are presented.

Conspicuous by its absence from the undergraduate program in tissue culture is an indepth discussion of tissue culture media and the role of hormonal regulation in shoot proliferation. The underlying premise behind this course organization is that students are inadequately prepared at this level to understand the intricacies of media formulation and that a brief mention of the roles of cytokinins and auxins is sufficient for them to grasp the concepts of regulation of differentiation. The essentiality for sterile technique, however, is very vividly demonstrated in the laboratory, where almost every student has a personal encounter with

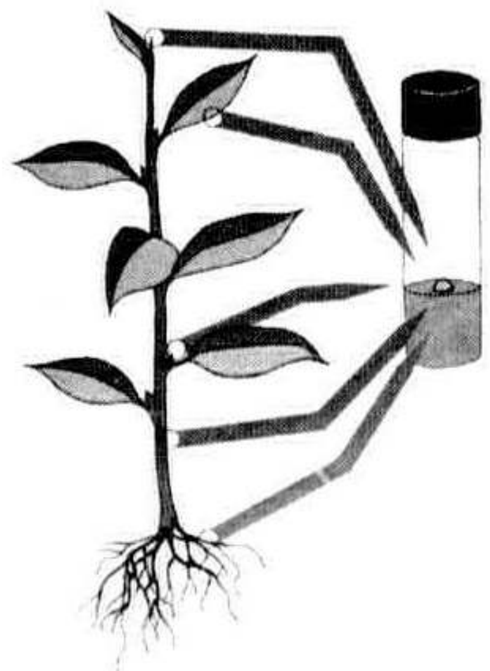

Figure 1. Explants for tissue culture may be obtained from shoot tip, leaf, lateral bud, stem or root tissue.

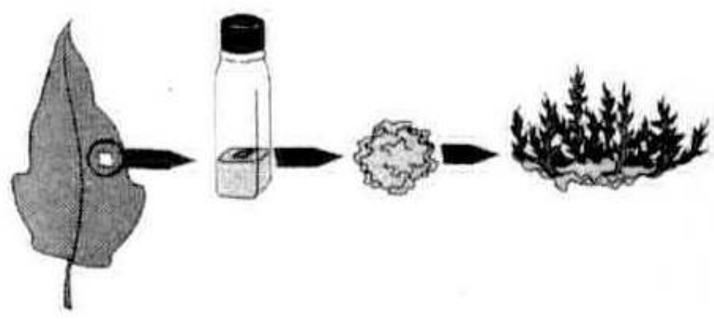

Figure 2. Leaf tissue explants of some species produce callus and then undergo shoot proliferation when placed in the tissue culture environment.

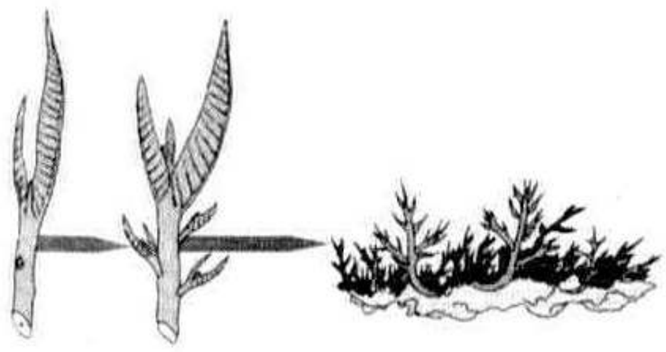

Figure 3. A shoot tip explant placed in tissue culture often multiplies by continuous growth of axillary shoots when apical dominance is overcome in tissue culture.

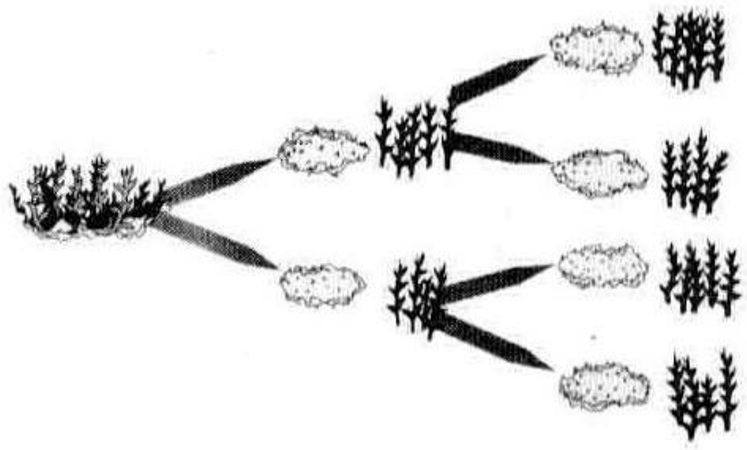

Figure 4. The ability to successively harvest shoot tips for rooting and increase the number of cultures by subculturing emphasizes the tremendous potential for mass propagation through tissue culture.

media contamination on a portion of his experiment.

The lecture portion of the tissue culture presentation in the plant propagation course is reinforced by allowing students "hands-on" experience in the laboratory. Students select an explant source, sterilize and rinse their tissue, and place the tissue on three different media. Greenhouse grown herbaceous material as well as woody trees and shrubs growing outdoors which are in a growth state favorable for tissue culture are all used as starting material. This diversity of plant species as well as the three media types allows for excellent and dramatic comparisons of tissue development in culture.

The undergraduate course in plant propagation at Ohio State University and at many other universities provides a good introduction to tissue culture technology. However, these students cannot be expected to fulfill the industry's need for tissue culture technicians or managers without a considerable amount of further educational or on-the-job experience.

Graduate level training and advanced individual studies (Horticulture 715, 293, 593, 993) provide students with more of the fundamental experience and knowledge required of tissue culture technicians and laboratory managers. Included in their flexible and individually designed programs are courses in the basic plant sciences, plant pathology, microbiology, and organic chemistry (Fig. 5). Additionally, graduate level courses should emphasize the "science" of tissue culture itself, including plant morphogenic responses and chemical control of growth and differentiation *in vitro*. Through their own research programs, students not only learn the detailed responses of the species with which they are working but, more importantly, they learn how to take a scientific approach to problem solving and research on any species.

Complete mention of the specific topics which are covered in the advanced tissue culture courses is beyond the scope of this essay. Several of the fundamentals are discussed. The first fundamental for introducing a species into culture is obtaining sterile explants. Emphasis is placed upon taking actively growing tissues, preferably from a greenhouse grown source. Students are taught simplified procedures for media preparation and storage. The importance of conducting experiments to test the effects of auxin and cytokinin interactions on the path of culture differentiation is demonstrated. Research applications other than mass propagation are stressed in Horticulture 715, including the techniques of cellular selection, protoplast isolation and culture, somatic hybridization, and meristem culture to obtain disease and virus-free stock.

Experience in evaluating the retention of knowledge by individuals after exposure to the teaching program in tissue culture at

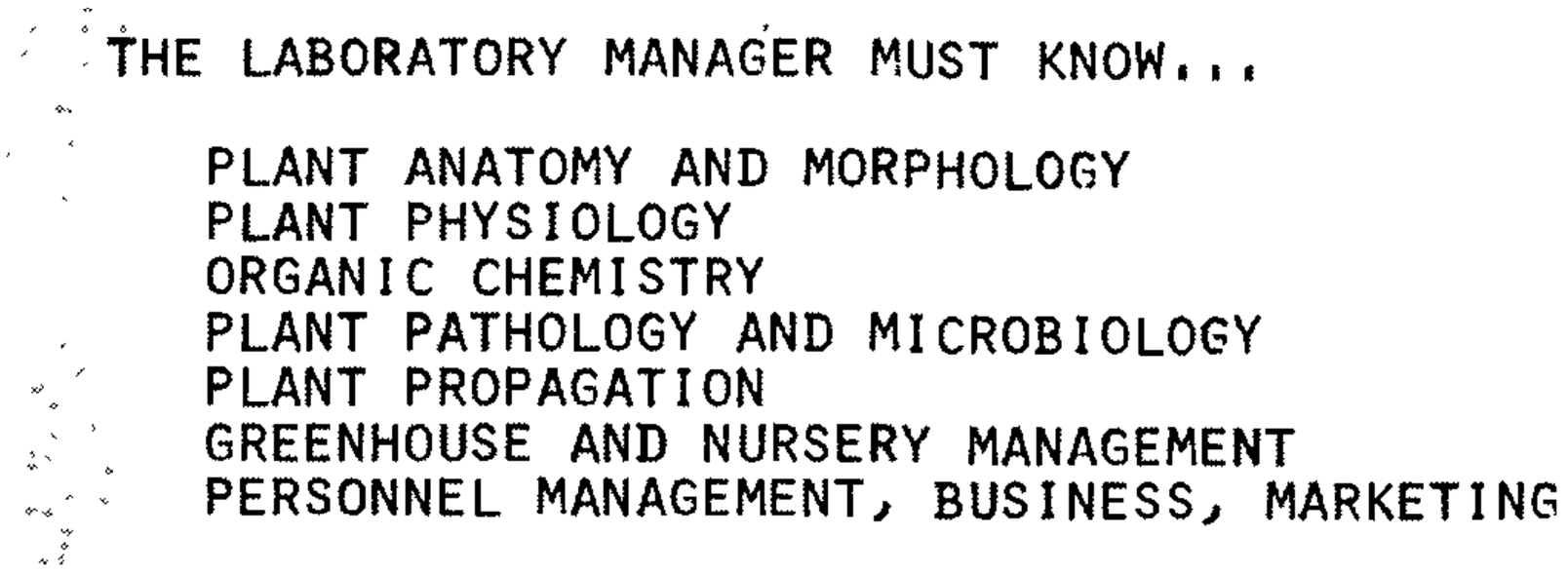

Figure 5. The manager of a tissue culture laboratory must have sound fundamental training in the physical, chemical, and plant sciences

the different levels has led to the following summaries The plant propagation student, after only an abbreviated introduction to tissue culture technology, has grasped the concept of mass propagation but cannot effectively function in the commercial laboratory without on-the-job training. This evaluation may come as no surprise to the members of the industry since they tend to view most college graduates as deficient in practical knowledge of all phases of plant propagation. The commercial tissue culture laboratory must seek a person with advanced training in tissue culture for supervisory and management positions. These individuals may be weak in the areas of business and management, but should have an excellent grasp of the basics of tissue culture technology.

As a final summary, some reiteration should be made of a concept mentioned in introducing this essay. A communication gap between industry and academia resulted in delays in the commercial implementation of tissue culture technology. Unless more efficient communication between the groups in fostered, this gap will also be reflected in the teaching programs in tissue culture and plant propagation.

SEED PROPAGATION LABORATORIES AT PENN STATE UNIVERSITY

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At The Pennsylvania State University there are three plant propagation courses, each at a different level. The first one is for our two year diploma students and it emphasizes the practical