It provides real life learning experience in propagating, growing, record-keeping and sales. (d) Most important, it motivates the capable student and prepares him for employment in commercial ornamental horticulture.

Based upon thirty years of experience we believe that our Agricultural Enterprise Program is the most important tool we have in recruiting, motivating, and placing qualified graduates in our vocational field.

MODERATOR VAN VEEN: Thank you, Howard. Next is Hudson Hartmann, University of California, Davis. Hudson:

TEACHING TECHNIQUES IN PLANT PROPAGATION

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There seems to be an increasing interest among students in plant propagation at the University of California, Davis Campus. Enrollment in the plant propagation course was quite stable for a number of years at about 35 students per year, then in 1971 it increased to 55, and in 1972 to 80. This class is given in the spring quarter, running 10 weeks, from about April 1 to June 10. It consists of two 1-hour lecture periods and one 3-hour laboratory period per week. Several laboratory sections per week are given, depending upon the enrollment. Twenty students is the maximum per laboratory section. One-third to one-half of the enrollment has been graduate students; a sizeable percentage of the enrollment is foreign students. Various majors are represented — such as plant science, environmental horticulture, agricultural education, agricultural science and management, pomology, viticulture, international agricultural development, and botany. It is an upper division course with a prerequisite of general botany or a general plant science course.

Eighteen lectures are usually given with 2 mid-term examinations. The lectures follow the theoretical chapters in Hartmann and Kester's "Plant Propagation: Principles and Practices" (1), which is used as the text. Considerable use is made of visual aids, chiefly 2 x 2 slides, to avoid the use of time-consuming drawings on the blackboard and to illustrate situations that facilitate explanations. Reading assignments are made of many of the chapters in the text, but xeroxed hand-outs are also distributed, giving new information which has appeared in scientific journals since the text was published. Every effort is made to provide students with the most recent information and to instill in them the concepts of scientific inquiry filling the gaps in our knowledge of the subject. In lecturing, it is important to avoid repeating ("parroting") what the students have already read in the text.

Subjects discussed in the lectures are:

(1) Objectives of course. Milestones in propagation history. Basic types of propagation in relation to meiosis and mitosis. Nomenclature terms — cultivar, clone, line, etc.

(2) Seed development, structure, viability, storage. Uses of seedlings in propagation. Methods of maintaining genetic purity. Seed certification

(3) Seed germination — hormonal and enzyme relationships. Seed dormancy — types. Embryo dormancy; hormonal relationships.

(4) Factors affecting seed germination. Phytochrome relationships. Disease control during germination.

(5) Asexual propagation, nature and importance. The clone. Juvenility. Genetic variation in clones — mutations, chimeras.

(6) Virus and mycoplasma problems in clonal propagation. Production and maintenance of pathogen-free clones. Certification programs. Plant patent law.

(7) Anatomical development of adventitious roots in stem, root and leaf cuttings. Relation of natural hormones to root initiation.

(8) Effects of leaves and buds on rooting. Rooting co-factors. Bioassays. Rooting inhibitors. Polarity.

(9) Factors affecting regeneration of plants from cuttings — selection of material, etiolation, juvenility, timing.

(10) Treatment of cuttings; use of growth regulators, fungicides and mineral nutrients. Environmental conditions during rooting: physiological effects of mist; temperature and light relationships; propagating media.

(11) Micro-propagation in aseptic culture. Uses. History. General techniques; specific procedures for various tissues.

(12) Grafting and budding. History. Reasons for using. Seedling vs clonal rootstocks.

(13) Formation and healing of the graft and bud union.

(14) Factors influencing healing of graft and bud union. Polarity in grafting.

(15) Limits of grafting; incompatibility, types and causes.

(16) Stock-scion relationships. Theories for explaining rootstock influence. Rootstocks for tree fruits.

(17) Layering. Bulbs, corms, rhizomes, etc.

In the ten 3-hour laboratory periods in this course, the work is of an applied nature, with the students learning the techniques involved in all the major propagation methods. However, the laboratory exercises are set up on an experimental basis where possible to elucidate the principles emphasized in the lectures. The laboratories are rather highly structured with materials prepared in advance for the students so that during the laboratory periods as much meaningful work as possible can be accomplished. Direction sheets are prepared for each laboratory and handed out a week in advance — with appropriate reading assignments — so that the students will be familiar with the subject material. In the first 4 laboratory periods students work in groups of two, or sometimes three.

Seeds. There are two laboratory periods on seed germination in which seven projects are done. The students essentially plant seeds in flats of germination media (the Cornell peat-lite mix) which are placed in the greenhouse; they make weekly seed germination counts for 5 weeks. A report is required for these 7 projects. The work done varies from year to year, but typically the projects used are:

(1) Effect of length of stratification period at a single temperature (41° F) on seed germination. Seeds of 5 or 6 woody species are available from which they select one. The stratification has already been done so they have only to plant the seed.

(2) Same as (1) except that the stratification time is fixed but various stratification temperatures: 32°, 41°, 50°, 68° (moist) and 68° F (dry) are used. Again seeds of 5 or 6 woody species are available from which the students select one.

(3) Seeds are soaked in various concentrations of gibberellin and combinations of gibberellin + cytokinin (compared to stratification), to demonstrate the influence of these materials in promoting germination.

(4) Seeds, such as *Cercis* and *Koelreuteria*, are planted to show the influence of "double dormancy". Various treatments are given but only those which both modify the seed coat and overcome embryo dormancy are successful.

(5) Planting of orchid seed in Erlenmyer flasks under aseptic conditions is done by each student, making use of a sterilized transfer chamber with the necessary equipment, plus a growth chamber for growing the seedlings.

(6) Seeds held under various storage conditions are planted to

illustrate the importance, with certain seeds, of storage conditions on subsequent germination. Citrus and oak seeds demonstrate this very well.

The students test all seeds before they are planted for viability, using the tetrazolium chloride test. Also samples of all seeds used in these exercises have been X-rayed by our Radiobiology Department and the x-ray photos are posted for the students to examine.

Cuttings. These are two lab periods on cutting propagation, with six projects; each student prepares reports for these projects. They vary from year to year but examples are given below:

(1) An air rooting tank is used in which cuttings of rapidly rooting species are placed, enabling the students to examine the developing adventitious roots weekly and to see the effects of wounding, IBA treatment, etc.

(2) Various growth regulators — auxin, gibberellin, growth retardent (Alar), ethylene (ethephon), cytokinin — are used for treating the base of cuttings to demonstrate the superiority of auxin in promoting rooting. The flats of cuttings are placed under mist in the greenhouse.

(3) Whole plants of various species are given to the students who make them up into various types of cuttings — root, stem, leaf, leaf-bud — all stuck in the same flat — to illustrate the various types of cuttings and to show that some types are successful and others not, depending upon the species.

(4) A project showing possible methods of reducing water loss from leafy cuttings is used by placing one group under mist, one in a closed poly frame, one in which cuttings are dipped in an anti-transpirant, and one control in the open greenhouse. Leafy grape cuttings have worked very well for this.

(5) A project illustrating the effect of leaf number in connection with IBA treatments has been very successful, using 4, 1, and 0 leaves per cutting, with and without IBA.

(6) A project with hardwood cuttings has been used with various treatments, such as wounding, IBA, boron, and fungicides. Some cuttings are inverted to show polarity effects.

Grafting. One laboratory period on root or bench grafting is done, with such material as grape on grape cuttings, pear or loquat on rooted quince cuttings and apple on apple seedlings. These are placed to callus in boxes, with the students examining some of the grafts later to note callus production in the cambial area and the healing of the union. All the material used is collected earlier and held in cold storage until needed. Both the whip graft and the machine saddle grafting, using a French-made grafting device —

see p. 431 — Hartmann and Kester (1), are used in making these grafts.

A second lab period in grafting and budding is utilized in practicing all the major grafting methods used in top-working trees. Also the T-bud and patch bud methods are practiced. Material in the proper growth stages is collected for the students to use in this work.

Following this practice lab the students have one laboratory period where they are taken to a special "student nursery" where young seedling peach and almond trees and rooted Marianna and *Rosa multiflora* cuttings and *Juglans hindsii* seedlings are available for T and patch budding. In addition, in this laboratory, seedling trifoliate orange (*Poncirus trifoliata*) trees in 2-gallon containers are available into which the students insert several buds — orange, mandarin, kumquat, lemon, etc. If these buds are successful the students are permitted to keep the plants at the end of the course.

The last grafting laboratory consists of top-working fruit trees in a special "student orchard". Five-year-old apple, pear, walnut or plum trees are used which are top-grafted to different varieties. Each student is assigned 3 trees, one top-worked by the bark graft, one by the cleft graft and one by side grafting.

The final laboratory period is utilized for a demonstration of structures and plant types used in propagation by bulbs, corms, rhizomes, stem and root tubers, runners, suckers, etc. as well as a demonstration of air layering, using *Ficus elastica* plants. This period is also used for taking counts of the rooting results from the cuttings prepared in the 3rd and 4th lab periods.

Two field trips are arranged in this course — one usually to the Oki Nursery in Sacramento, where a wide range of up-to-date nursery practices are seen. A second trip to a fruit tree nursery is made; this past year the Fowler Nursery south of Marysville, California was visited, where propagation of most species of fruit trees was observed.

LITERATURE CITED

1. Hartmann, Hudson T. and Dale E. Kester. 1968. Plant Propagation: Principles and Practices, 2nd ed. Prentice-Hall, Englewood Cliffs, New Jersey.

MODERATOR VAN VEEN: Thank you, Hudson. We were to have Jerry Mailman, California Department of Corrections, Soledad, on this panel but he was unable to be here. In his place, Ed Jelenfy, also a horticulturist of the same institution, will fill in briefly. Ed: