THURSDAY AFTERNOON SESSION

December 5, 1963

FIRST SECTION

The first section of the afternoon session convened at 1:15 p.m., Arthur J. Lancaster, Jr., Coleman Nurseries, Portsmouth, Virginia, moderator.

MR. ART LANCASTER: The first paper this afternoon will be given by Dr. Charles E. Hess, Department of Horticulture, Purdue University.

WHY CERTAIN CUTTINGS ARE HARD TO ROOT

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I would like to begin by describing some of the factors which can affect the rooting of a cutting, then go into how some of these factors may work, and end up with a few techniques which are used to increase the rooting capacity of difficult-to-root cuttings.

JUVENILITY

Figure 1 summarizes some of the factors which affect rooting. Juvenility, in my opinion, has a profound effect upon the rooting ability of a cutting. Cuttings taken from young plants almost invariably root better than do cuttings taken from older plants. For example, 31%, 18% and 9% rooting was obtained with cuttings taken from 1, 2, and 3 year old *Pinus strobus* plants respectively. In each case the same type of cutting was taken, using one year old wood (18). Therefore, even though you may use 'young' wood, if it is taken from an old plant, it will still be difficult-to-root. There are exceptions, of course, but the generalization is particularly applicable for difficult-to-root plants.

Most, if not all, plants go through a period of juvenility between the time they are in the seedling stage and until they flower. In some plants, the juvenile phase is quite clear because the plants actually look different. One striking example is *Hedera helix,* the English Ivy (9). During the juvenile phase, the plant is a ground cover with lobed leaves, redish stems and aerial roots. Mature plants are woody shrubs with entire leaves, green stems, and no aerial roots. Other plants have less obvious indicators of juvenility such as the presence of thorns on apple seedlings and the presence of needle-like leaves on junipers in the juvenile phase and scale-leaves in the mature phase. The length of the juvenile period is quite variable be-

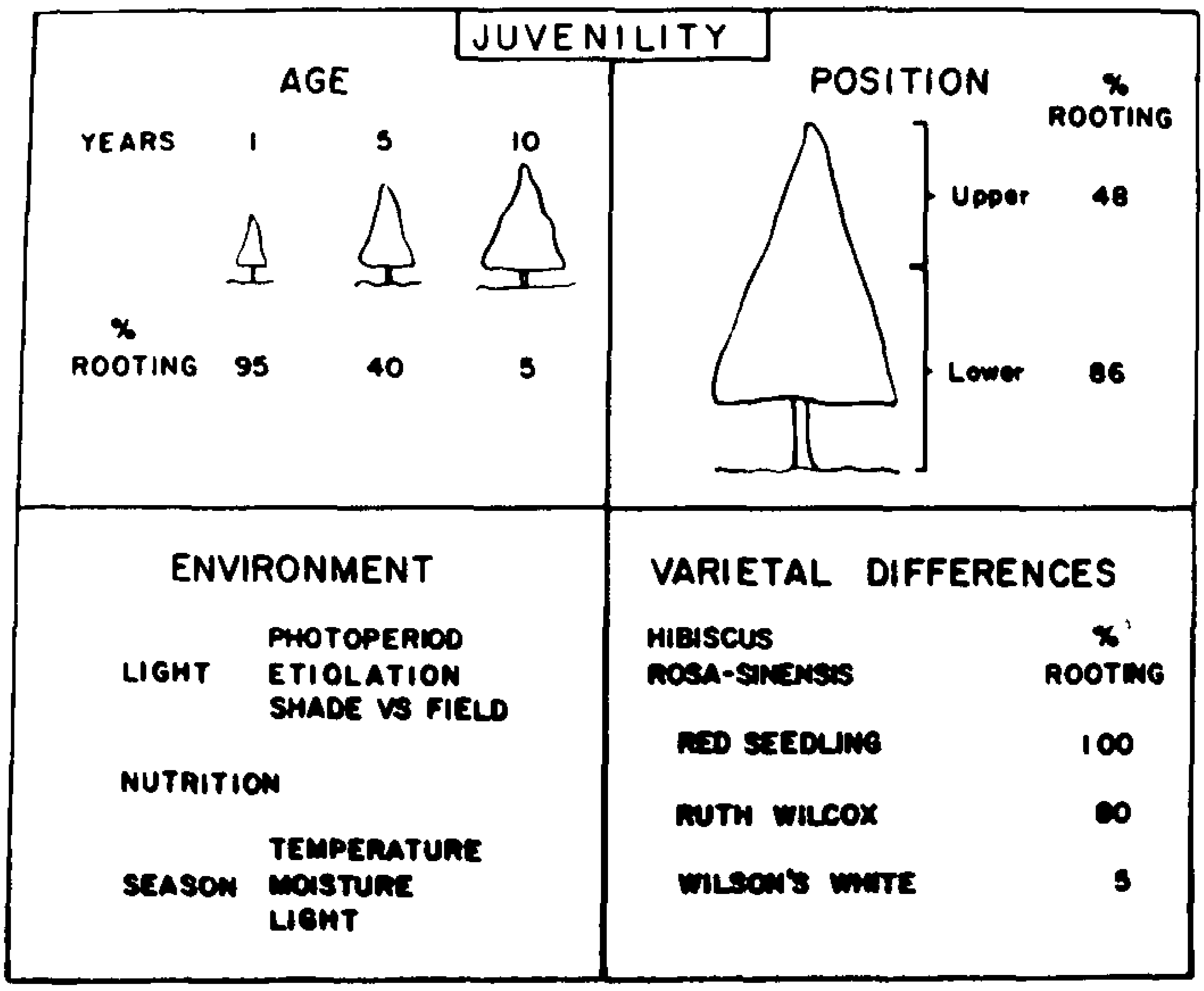

Figure 1 Factors affecting the rooting of cuttings.

tween species. It may be indefinite in the case of *Hedera* as long as the vines are allowed to grow along the ground (the mature form usually appears only after the plants have grown up a wall or a tree). In contrast, using the example of *Pinus strobus* given above, the juvenile period appears to be rather short as far as rooting ability is concerned. The plant may not have reached the seed producing stage and already be considered difficult or impossible to root. Therefore, there exists a transition between the highly juvenile, easy-to-root, seedling phase and the difficult-to-root mature phase.

An interesting feature of juvenility is that a plant does not become completely mature. The lower portion of the plant, close to the root system and including the root system, remains juvenile or at least has the ability to produce juvenile shoots. Thus, when an apple tree is severely pruned and shoots develop from the base of the plant, they are juvenile. They are called water sprouts, epicormics, or suckers and have characteristics of juvenility such as thorniness, rapid growth rate, and no fruiting spurs. Similarly, it is very common to find juvenile shoots of *Hedera* at the base of the mature, shrub form, *Hedera helix aborescens*.

Leaf retention late into the fall and winter is also an indication of juvenility. The triangle of leaves seen at the base of beech and oak trees indicates that part of the tree which is still juvenile.

The fact that the lower portion of a plant retains its juvenile condition is reflected in the rooting ability of cuttings taken from the upper and lower portions of a plant. As shown in Figure 1 cuttings taken from the upper portion of a cone bearing spruce plant rooted 48% while those taken from the lower portion, rooted 86% (5). Another example is the presence of root nodules (bubbles) on the stems of certain conifers such as *Juniperus chinensis* 'Hetz' and *Thuja occidentalis* 'woodward.' The nodules, which are preformed root initials and develop into roots very quickly in the proper environment, are found on the lower portion of the plants (24).

ENVIRONMENT

The environment also plays an important role in the ability of a cutting to root. As shown in Figure 1 some of environmental factors which have a major role in rooting are light, nutrition, and a complex of several elements of the environment expressed as seasonal variation.

LIGHT

Light is of major importance because it is the energy source used in the process of photosynthesis. The sugar which is produced by photosynthesis provides the energy needed for the thousands of reactions within the plant and also provides the raw material from which new substances are made.

In addition to being the plants' energy source, light affects plant growth and development in another way. The length of the day or the photoperiod can regulate the flowering of a plant. For example, a chrysanthemum is classified as a short day plant because under natural conditions it flowers in the fall when the days become short. Nitsch (11), Waxman (20), and Peringer (13) have demonstrated that long days on stock plants or on cuttings enhances the rooting response, either by faster rooting or by a larger, more branched root system. Plants such as *Weigela, Ilex, Buxus,* and *Cornus florida* are benefited by long days. However, the response is quite variable and it is not possible to generalize and say that long days should be used on all cuttings. For example, long days used on dormant evergreen cuttings may stimulate vegetative growth before rooting. Another complication is that in some cases the presence of flower buds decreases the rooting ability of a cutting (2, 12). Therefore, if a long photoperiod also promotes flower initiation, the stimulatory effect upon rooting may be lost or neutralized.

We have stated that light must be supplied to the stock plant because it provides the energy required for photosynthesis. In contrast, the actual process of initiation appears to be favored by darkness — that is darkness in the area where the root initials are being formed. As has been discussed this morning (8) and in previous Proceedings of the Society (17) etiolation (the development of plants or plant parts in the absence of light) has a great stimulatory effect upon root initiation. The process of etiolation is utilized each time a cutting is stuck into a medium, soil is placed around the base of a plant in layering, or when sphagnum moss is wrapped around a stem in an air layer. However, the beneficial effects of etiolation are greater when the stem section is truly etiolated (i.e. it has developed without having been exposed to any light) as compared to blanching (covering a stem after it has developed in light). The blanched stem may look similar to an etiolated stem, but the internal structures will be different. For example, there will be more fiber tissue present in the blanched stem.

A phenomenon, probably related to etiolation, is that some cuttings taken from shade grown plants root more easily than do cuttings taken from plants grown in sun (15). There is a smaller amount of lignification and fiber formation in shaded plants with the result that a greater number of cells are available to form root initials.

NUTRITION

The nutrition of a stock plant can affect the rooting ability of cuttings taken from it (6, 14). Of the major elements, nitrogen seems to have the greatest effect upon rooting. A high level of nitrogen is generally detrimental as compared to a medium or low level of nitrogen particularly when soft wood cuttings are taken (14). The reasons why a high level of nitrogen is detrimental may be associated with a stimulation of vigorous vegetative growth. The soft, succulent growth is believed to be low in sugars which are essential for rooting as has been mentioned above. In addition there is some evidence that other substances essential for rooting may be in short supply in rapidly growing shoots.

Two minor elements have been shown to have an effect upon rooting. One is zinc (16) and the other is boron (7, 22). Zinc is essential for the synthesis of tryptophane which is a precursor of indoleacetic acid. Boron does not appear to stimulate the actual process of root initiation, but does stimulate the growth of the roots once they have been initiated. Low concentrations are used. For example, Weiser used 50 and 100 ppm (50-100 mg/1) when treating deciduous azaleas and dwarf rhododendrons (23).

The addition of nutrients to cuttings is receiving increasing attention, particular in the application of nutrients through mist. At present there does not seem to be any beneficial effect upon the rate of root initiation. However, the establishment and growth of the cuttings after rooting was greatly enhanced with the addition of a complete fertilizer in the mist (19).

SEASONAL VARIATION

We all recognize the fact that for each plant there seems to be a time which is best for taking cuttings. The use of mist and softwood cuttings has increased the time when cuttings may be successfully rooted. However, timing is still very critical with plants which are difficut-to-root. For example, Waxman reported a very short period of time near the end of March when *Sciadopitys verticillata* could be rooted in commercial feasible percentages (21). The causes of seasonal variation are very difficult to explain because the variations are a result of complex interactions between such factors as temperature, moisture supply, and light — both intensity and day length. I will not say more about this area because Dr. Lanphear will present a paper on seasonal responses in evergreen cuttings later in the program (10).

VARIETAL DIFFERENCES

Perhaps one of the most intriguing problems in plant propagation is varietal differences in the rooting ability of cuttings. Why is it that closely related plants grown under identical conditions vary so much in their rooting response? Take, for example, three varieties of *Hibiscus rosa-sinensis* grown under the same conditions and using similar cuttings from plants of equal age. Cuttings from a red variety rooted 100%, 80% rooting was obtained with Ruth Wilcox, and 5% rooting with Wilson's White.

We feel that a part of the cause of the varietal differences can be attributed to differences in the ability of the cuttings to manufacture substances essential for rooting. Auxins, such as indoleacetic acid (IAA), do not seem to be limiting in the difficult-to-root cuttings. However, other substances which may act as cofactors with IAA are found in smaller amounts in the difficult-to-root cuttings (9). The chemical nature of the rooting cofactors has yet to be established, but present indications are that purines, phenolic compounds and terpenes are involved.

A frequently observed characteristic of difficult-to-root varieties is the presence of fibers, particularly outside of the phloem. Beakbane (1) has made a correlation between the continuity of the phloem fiber ring and rooting ability of apple cuttings. If the ring was only 41% complete, rooting was excellent, 64% continuity resulted in good rooting, 75% continuity — fair rooting, and 84% continuity — poor rooting.

There are two ways in which the problem of lignification can be overcome. One is by using very soft cuttings which have not developed secondary tissues. In fact, the reason the cuttings are "soft" is because lignification and fiber formation have not taken place. Etiolation provides a second way in which lignification can be prevented. Lignin is a complex substance made up of phenolic acids, and light is essential for one of the steps in phenolic acid synthesis. Etiolated tissues are very low in phenolic acids and little or no lignin is formed.

A very interesting side benefit from blocking lignin formation by etiolation may be the accumulation of precursors of phenolic compounds which in turn may be stimulators of root initiaton. Thus, etiolation may have a dual effect. One, it blocks lignification and fiber formation and therefore more cells are available for cell division, and two, it may cause the accumulation of a root promoting substance.

Figure 2 shows the technique used to etiolate a *Hibiscus* stem and Figure 3 shows the appearance of etiolated and non-etiolated *Hibiscus* stems. Notice that root initiation took place during the etiolation process.

I mentioned in the discussion of varietal differences that some cuttings may be difficult-to-root because they do not manufacture a sufficient quantity of the substances essential for rooting. A technique which can partially overcome this problem is to girdle a shoot, leave it on the stock plant for a period of time. and then make the cutting as shown in Figure 4. The longer the shoot is left in the girdled condition before the cutting is taken, the better will be the rooting response. Figure 5 shows a comparison of the rooting response of an easy (Red) and an intermediate in rooting ability (Ruth Wilcox) *Hibiscus* after being girdled for 0, 9, 18, and 27 days. Notice that the easy-to-root red variety exhibited the greater response to the girdling treatment. The reason is believed to be due to a higher production of root promoting substances in the red variety and therefore more were available for accumulation above the girdle.

I started out by saying that juvenility played a very important role in the ability of a cutting to root. I would like to finish by giving two examples of commercial practices which perpetuate the juvenile phase. The examples are shown diagrammatically in Figure 6. Hedges, as suggested by Garner (4)

Figure 2. Technique used to etiolate a *Hibiscus rosa-sinensis stem.* The virmiculite was added every other day as the shoot grew up through the cone.

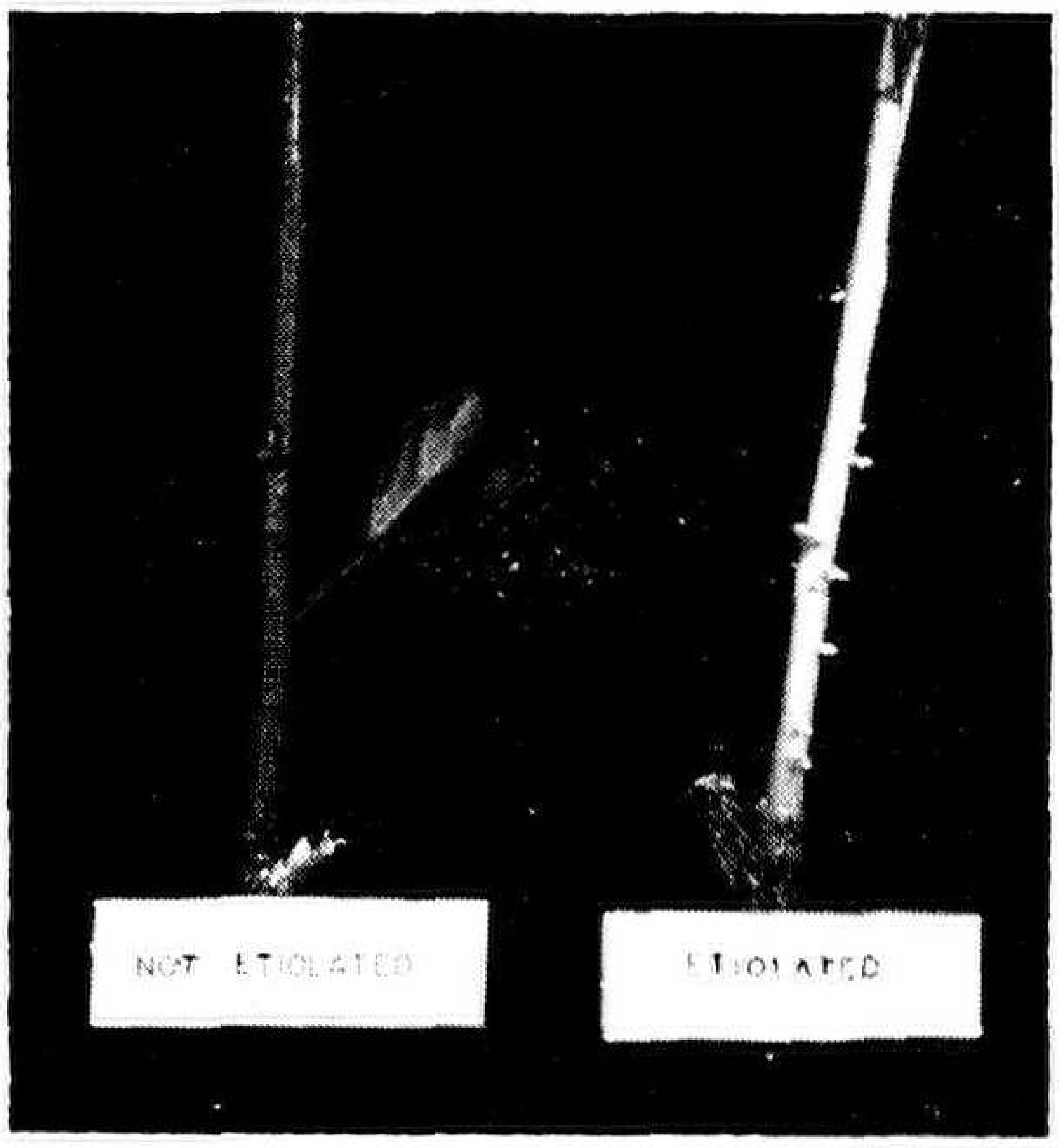

Figure 3. A comparison of an etiolated and non-etiolated stem of *Hibiscus rosa-sunensis.* Root initiation took place during etiolation.

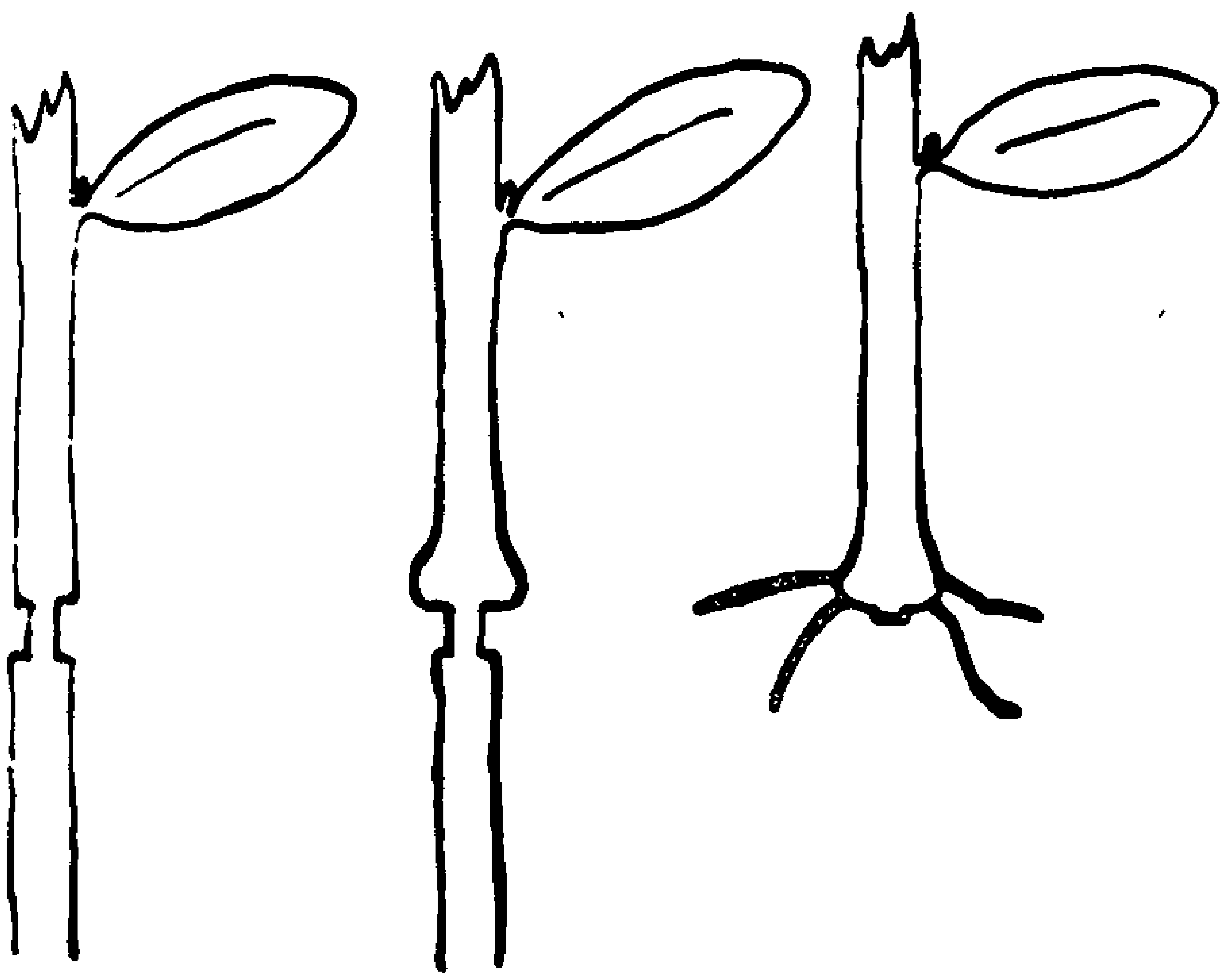

Figure 4 Girdling to promote the accumulation of root promoting substances before taking a cutting.

and stool beds perpertuate the juvenile state because the stock plants are continuously cut back. Thus, the new, vigorous shoots arise only from basal, juvenile portion of the plant.

Finally, the process of root initiation seems to cause a degree of rejuvenation, at least in respect to rooting ability. It is commonly reported that cuttings taken from cuttings root better than the original cutting taken from a mature stock plant. For example, Dr. Sylvester March made this statement in the 1962 Proceedings; "We have propagated Freeman (Magnolia) hy-

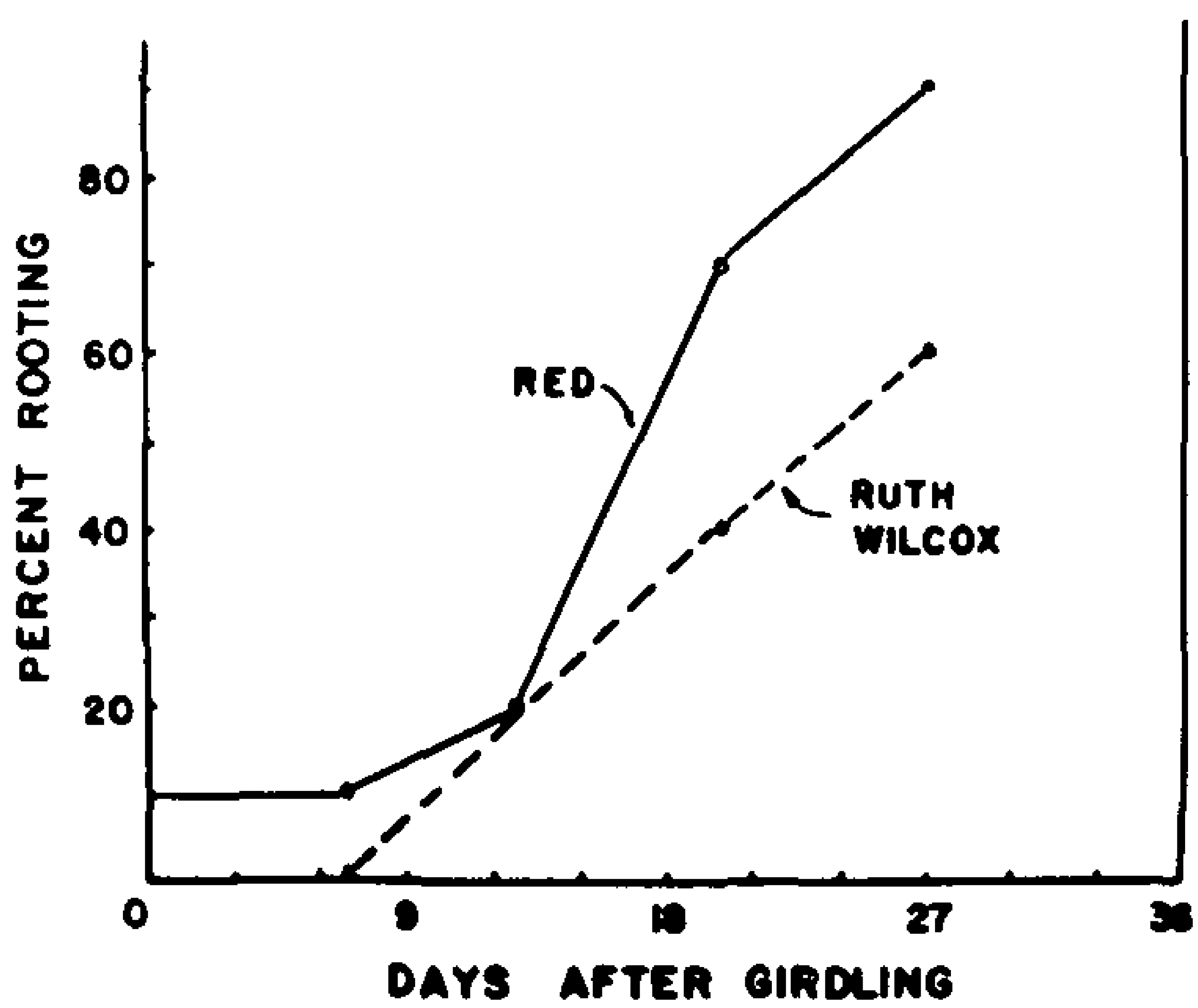

Figure 5 The effects of increasing numbers of days of girdling upon the percent rooting of two varieties of *Hibiscus rosa-sinensis*

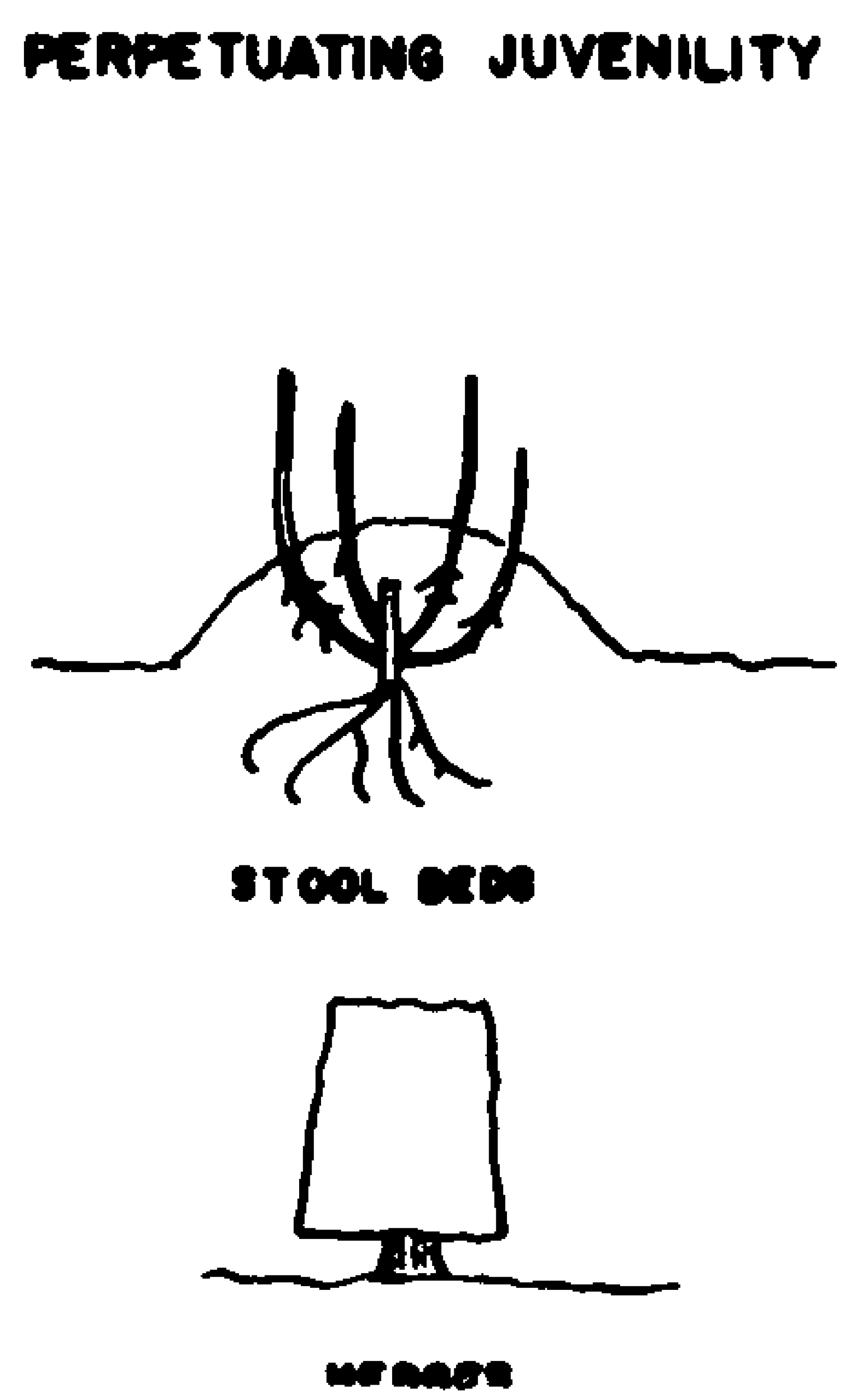

Figure 6. Commercial techniques used to perpetuate juvenility.

brids, using cuttings from young plants. We find this is the key to the whole problem. If a cutting is taken from the original tree, the results are very poor. It is a matter of getting some of the original cuttings to root and then to take your cuttings from the young juvenile plants."

The process of root initiation is very complex and can be influenced by many factors. However, we are gradually identifying the important factors affecting root initiation and are learning how they actually work to alter the rooting process. I hope that the information we have covered will provide a better understanding of why certain plants are hard to root and perhaps give you some ideas of what you can do to improve the rooting ability of difficult-to-root cuttings.

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MR. ART LANCASTER: Thank you very much, Charley. The next paper will be given by Dr. Richard Zimmerman, Texas Forest Service, College Station, Texas.

ROOTING COFACTORS IN SOME SOUTHERN PINES

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INTRODUCTION

The Tree Improvement Program of the Texas Forest Service is concerned with the selection and breeding of superior strains of southern pines for paper pulp and lumber. One of the problems encountered in this program has been the vegetative propagation of selected trees. Since only mature trees are selected, rooting capacity is low (6, 7) and the selections have been propagated by grafting in the past. For our purposes, this has the disadvantages of (1) a different genetic constitution of the stock and scion, (2) possible incompatability between the stock and scion, and (3) higher cost.

Attempts at working out a satisfactory technique for propagating older pines from cuttings met with little success. Accordingly the decision was made to begin a basic investigation of rooting in pines. The purposes were, first, to study root initiation in pines and, second, to determine the relationshp between juvenility and root initiation. The first phase of the research has been to determine if the rooting cofactors that Hess (1) reported are present in pines.

MATERIALS AND METHODS

Pine needles are collected and dried by lyophilization or "freeze-drying." The dried tissue is ground up and a 100 milligram portion weighed out. This is extracted with absolute methanol for two hours at 0° C. The extracts are filtered, dried, and dissolved in a small amount of 95% ethanol. The concentrated extract is applied as a streak on a two inch wide strip of Whatman 3MM chromatographic paper. The chromatograms are developed by ascending chromatography with isopropanol-water (4:1 v/v) following a 15 hour equilibration period. Development of the chromatograms is stopped when the solvent