Plant Propagation—The Union of Art and Science

I would like to start my presentation with a word of sincere appreciation to arboreta and botantical gardens in general and the Arnold Arboretum in particular for the contributions made to the field of plant propagation. An appropriate example, during the Centennial Year celebration, is the excellent research Mr. Alfred Fordham has conducted and published in the area of seed propagation. He has contributed to our knowledge of the basis of dormancy in seed as well as practical methods by which a horticulturist can overcome seed dormancy. Plant propagation is truly the union of art and science. I would like to present a number of plant propagation techniques where this phenomenon can be exemplified.

I will continue with seed propagation. It has been known for some time that sphagnum moss improves the germination of seedlings. In part the favorable response is due to physical characteristics such as good aeration, and good moisture holding capacity. There is also apparently a fungistatic effect of sphagnum moss because damping-off usually does not occur when sphagnum moss is used as a germination medium. We were curious about the nature of the fungistatic agent and we made a number of extracts to see if we could separate it from the sphagnum moss. We found that there was in fact a substance, which could be extracted from the sphagnum moss, which prevented the growth of damping-off organisms. We also found associated with the sphagnum moss a bacterium, which when grown under culture conditions, produced a substance which inhibited the growth of organisms such as *Pythium*, and *Rhizoctonia* which can cause damping-off in young seedlings. It may be that the bacteria is the actual source of the fungistatic material associated with sphagnum moss. It is commonly recommended that the sphagnum moss should not be sterilized prior to its use because much of the fungistatic effect is lost. It could well be that the loss is due to the killing of the bacteria in the sterilization process.

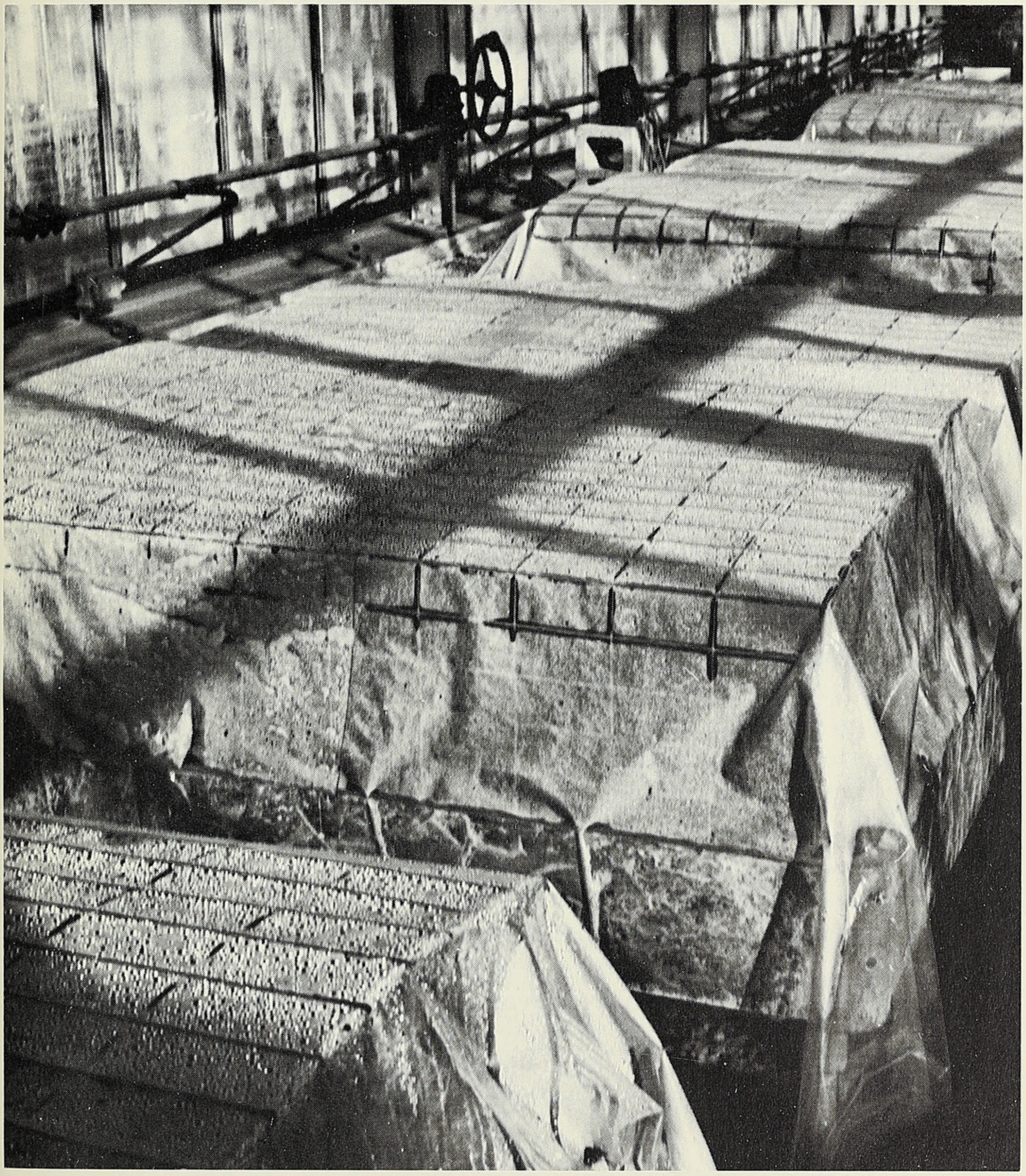
I would now like to turn to the propagation of plants by cuttings in which we will see a wealth of examples in which art and science have been united to produce successful propagation techniques. When a cutting is taken from a plant, one of the primary responsibilities of the propagator is to prevent moisture loss. If the leaves are retained in a turgid condition, photosynthesis will occur leading to the production of sugars and other substances essential for root initiation which move down the stem and accumulate at the base. When a sufficient level of substances have accumulated, cell division is initiated and root differentiation follows. One of the techniques used to control water loss is to increase the relative humidity surrounding the leaves of the cuttings. The result is that the tendency of water to leave the leaf is as great as it is to enter and an equilibrium is reached. One of the first structures that was used to achieve this equilibrium was the bell jar. However, in addition to being an excellent moisture barrier, the bell jar with its restricted space also becomes a heat trap. If it is exposed to direct sunlight, the temperature will reach a point at which the plant tissues are severely damaged, if not killed. A grafting case, although more efficient in operation, uses the same principle of trapping moisture around the cuttings so as to prevent any net loss of water. Plastic tents are once again more efficient, but are based on the same principle. In each case it is necessary to provide substantial amounts of shade during sunny periods to prevent excessive accumulation of heat.

A unique variation in the use of shade to reduce the detrimental effects of direct sunlight was introduced by Mr. Guy Nearing who developed the Nearing Frame. The propagation unit consists of a cold frame covered by a reflector with an opening to the north. The cuttings receive only indirect or reflected light and therefore are not subjected to the intense heat of direct sunlight.

An alternative to building up moisture in a confined space is to use a larger structure and introduce moisture by means of a humidifier. The larger volume of air provides a greater buffer to fluctuations in temperature. However, it is still essential to provide shade for even under these conditions, the large volume of air will be heated excessively and in many cases plant tissues will be damaged.

In the early 1950's a new dimension was introduced into the control of water loss from cuttings. This was mist propagation in which a fine spray of water was applied intermittently to the cuttings. Not only was moisture introduced into the air, but

Polyethylene plastic covered propagating chambers used in autumn at the Dana Greenhouses, Arnold Arboretum. This plastic is air permeable yet vaporproof. The high relative humidity maintained reduces transpiration and prevents the cuttings from wilting. Photo: A. Fordham as the moisture reached the leaves and then evaporated from them, it had a cooling effect. The cooler leaf temperatures reduced the rate of evaporation of water within the leaf and therefore reduced water loss. Since a confined space was no longer necessary to retain humidity, the cuttings could be propagated under open conditions and much higher light intensities could be used. As a result the cuttings were favored by greater potential rates of photosynthesis and since leaf tissue temperatures were reduced, the rate of respiration was reduced also. As a result photosynthate actually accumulated under the conditions of mist propagation whereas in conventional propa-



gation techniques, carbohydrates were used at a rate greater than their manufacture.

The ultimate in plant propagation in terms of environmental control is plant tissue culture. Under these conditions the light, moisture, and even the makeup of the nutrients on which the tissues are grown are very specifically controlled. In fact it is possible by manipulation of the media to determine whether shoots or roots, or both, are formed on the plant tissue cultures.

I would like to now consider some internal factors which effect the rooting of cuttings and one of them which has been of particular interest is juvenility. Juvenility can be expressed as the effects of the age of plants from which cuttings are taken. The younger the plants are, the greater are the percentages of rooting. It can be expressed also in the position on the stock plant from which cuttings are taken. It turns out that plants retain their juvenile characteristics in the lower portion of the plant. Therefore, if cuttings are taken from the base of the plant, the percentage of rooting is often higher than for cuttings taken from the upper portion of the plant. Propagators have taken advantage of this technique by maintaining stool beds in which the plants are constantly cut back and shoots are forced from the root system. The basal shoots have juvenile characteristics and are quite easy to root. Another alternative is to maintain the stock blocks from which cuttings are taken in the form of hedges. Again the propagator ensures that the shoots are obtained from the lower portion of the plant. An excellent example of a plant in which the effects of juvenility can be studied is *Hedera helix*. The juvenile and mature forms have distinct morphological differences. The juvenile form grows horizontally, has palmate leaves, and is used frequently as a ground cover. In contrast, the mature form grows upright as a shrub, has entire leaves, and is capable of flowering and producing fruit. The juvenile cuttings root very readily with or without a treatment with root promoting substances. In contrast, the mature cuttings root with extreme difficulty even though root promoting substances may be added. We have found that there are no substantial differences in the auxin or root promoting substances, or root inhibiting substances, in the juvenile and mature tissues. However, another group of substances which we have referred to as rooting co-factors appear to be in greater concentration in the juvenile tissues. We have developed a hypothetical scheme of adventitious root initiation shown in Figure 1 which is based on experiments conducted with the juvenile and mature forms of *Hedera helix* and other easy- and difficult-to-root cuttings. We

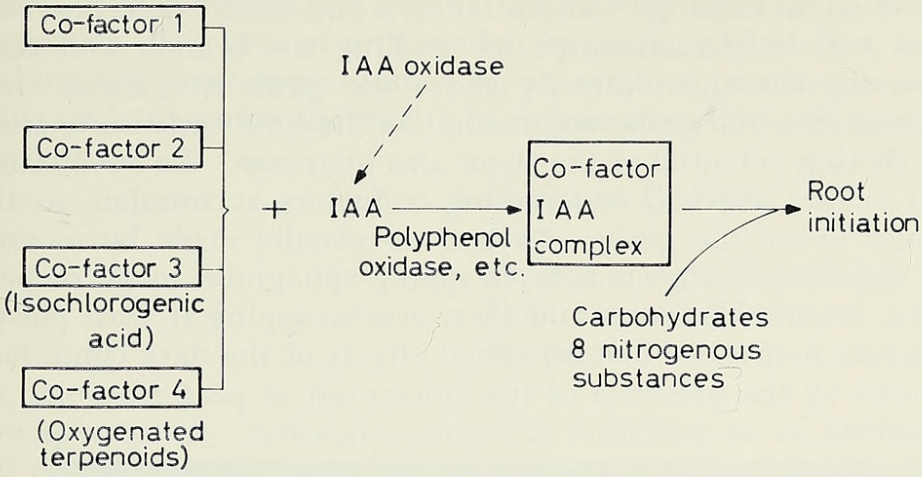


Figure 1. A hypothetical scheme of adventitious root initiation.

From: Hess, C. E. 1968. "Internal and External Factors Regulating Root Initiation" in Root Growth, *published by Butterworths, London, England.*

feel that easy-to-root cuttings contain four or more rooting co-factors and have an adequate supply of auxins. The auxin and the co-factors form a complex and if there is an adequate supply of carbohydrates and nitrogenous substances, root initiation will progress. If the cutting is difficult to root, it may be due to the lack of an auxin. This can be corrected by supplementing the auxin with a synthetic material such as indolebutyric acid, or naphthalene acetic acid. If, however, the cutting fails to root even with an auxin application, it may be due to the lack of one or more of the co-factors. In fact, the degree of difficulty can be an expression of how many and how much of the co-factors are missing. Therefore, we see that the rooting of cuttings involves the art of providing the proper environment so that cuttings will retain ample amounts of moisture and under these conditions a highly complex sequence of biochemical events can take place leading to the initiation and differentiation of root primordia.

Now let us turn to the techniques of propagation by layering. One of the factors in layering that can effect its success is the girdling of the stem prior to placing rooting media around the branch. The purpose of the girdle is to interrupt the downward movement of the root promoting substances which are synthesized by the leaves and buds. As this material accumulates, just as in the cuttings, root initiation is stimulated. This phenomenon can be demonstrated by girdling the branch and then removing the shoot directly above the girdle at various time periods after the girdle was made. As the time period increases, the rooting potential of the shoot also increases. We have found that sugars, auxins, and rooting co-factors accumulate in the tissues above the girdle. Layers are usually made by mounding soil around the stem or wrapping sphagnum moss, or peat moss, around the stem and then over-wrapping it with plastic to retain moisture. The beneficial effects of the dark conditions created by the presence of the sphagnum or peat moss can be described as an etiolation or degreening effect. In many plants the initiation of roots can be inhibited if the area in which the initiation is to take place is exposed to light. This is quite in contrast with the leafy area of the cutting which should be exposed to light in order to promote photosynthesis.

Finally, I wish to discuss very briefly propagation by grafting. This is an area in which art predominates over science. Comparatively little is known about the physiology of graft union formation and what can be done to accelerate it. It is known that the botanical relationship of the graft partners must be very closely observed. It is nearly impossible to graft plants of distant botanical relationships. The phenomenon of incompatibility plays a major role in unsuccessful graft unions. Techniques such as the use of an intermediate stock, have been used to overcome the problem of incompatibility but the examples are rather few. Attempts have been made to accelerate graft union formation through the use of growth promoting and cell division

stimulating substances. Although a few instances of success have been reported, the general experience has been a lack of response. The area of propagation by grafting, therefore, is one which has great opportunities for research to provide the scientific basis to match the wealth of information that can be classified as art.

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Mist system in use for propagation at the Arnold Arboretum greenhouses. Photo: P. Bruns