Down here in the front row are some of my best friends, good nurserymen in this region, progressive men who are growing new types of plant materials, and who have problems. I think in a meeting of this sort you will discover that you can take your hair down and as one of us advances we all advance. Let's give as much as we can to this meeting, with the hope of getting out of it just as much as we can. For Mr. Scanlon and for myself and for the horticulturists of Cleveland, I would like to say we are very happy to have you all here today. We hope this will be even more successful than the two previous conferences. Thank you very much. (Applause)

PRESIDENT WELLS: Thank you, Mr. Davis, thank you very much. I am sure all of us here are determined to do just that.

A little later in the afternoon we will give you some information about this evening meeting, but before that, we have a paper which I think is going to be of real interest and of fundamental value to us all.

One of the aims of this Society, which is only just beginning to take shape, is to interest speakers in what might be called scientific papers and information obtained from scientific sources with downright practical knowledge obtained from the members who in the final analysis have to apply the scientific knowledge to their day-by day work.

We want to try to present a balanced diet of both types of papers. Roger U. Swingle of the United States Department of Agriculture, will present the first paper. Mr. Swingle is a rather quiet and unassuming sort of person and I feel quite sure that tucked underneath his quiet, smiling countenance there is a tremendous fund of really fundamental knowledge of plants which we all need. We hope and believe that he will present something which will make all that follows a little more clear to us.

Roger U. Swingle presented his paper on "Some Facts and Theories Concerning Compatibility in Relation to Plant Propagation." (Applause)

Some Facts and Theories Concerning Compatibility In Relation to Plant Propagation

ROGER U. SWINGLE, Senior Pathologist
Agricultural Research Service
United States Department of Agriculture

The essential role of compatibility in plant propagation by graftage and seed production has been recognized for many years. Its importance is reflected by the numerous reports in plant science literature on incompatibilities or uncongenialities and their effects on plant production and utilization. It has been possible for me to review only a very small part of the literature dealing with this subject but I have attempted to include more recently published reviews and articles in order that some of the basic aspects of incompatibility could be presented.

Incompatibility as applied to aspects of plant propagation has been variously defined. The term itself means "not capable of coexistence in harmony," "lacking affinity," "intolerant" or "antagonistic." Argles (1), in his review of literature on graft incompatibility, considers it to be an inherent antagonism between certain stocks and scions, the cause or causes of failure or abnormalities arising out of the nature of the two plants. He believes that the form or type of failure is governed or influenced by environment and treatment. However, incompatibility should not be applied to failures that are caused by environment or treatment. Bradford and Sitton (3), in an excellent paper on defective graft unions, characterize incompatible unions as those in which there is failure to maintain cambium continuity. Roberts (10), in a review of some of the theoretical aspects of graftage, states that "Compatibility refers to the long-time success of a graft for economic, esthetic or scientific purposes. Anything less is incompatibility." This broader concept considers compatibility as any influence between stock and scion and not merely effects arising directly from the union

Compatibilities affecting seed production or hybridization are of equal or possibly greater importance than their effect on graftage. Incompatibility in such cases affects phases of the normal reproduction processes. It is a common cause of self- or cross-sterility and may offer a natural "curb" on either inbreeding or outbreeding. Although frequently being an exasperating hindrance to the desires and objectives of the plant breeder it provides stability of species.

Incompatibility in Relation to Seed Production

Incompatibility in relation to hybridization and seed production has received considerable study, especially in the fields of food and forage crops. Some workers have applied the term "incompatibility" only to failures of functional gametes to achieve union or fertilization. Others consider incompatibility to include post-fertilization failure of the embryo or endosperm to develop in a normal manner.

Many flowering plants will not produce seed when self-pollinated. However, viable seed is produced from reciprocal crosses with other plants, showing that both pollen and egg cells are functional. Also, some plants produce seed when crossed in certain combinations but not in others. Such cases of self- and cross-sterility are commonly caused by incompatibility between pollen and pistil.

Incompatibility may occur between pollen and stigma of the pistil, resulting in failure of pollen to germinate or the pollen tube to penetrate the stigmatic surface. With other plants incompatibility may occur between pollen tube and tissues of the style. In this case the pollen tube may either disintegrate after penetration of the style for varying distances or growth of the tube may be so greatly retarded that the egg cells or ovules disintegrate before fertilization can be accomplished In still other combinations, fertilization may occur only to be followed by degeneration and disintegration of the immature embryos. Finally, a mature embryo may be formed but fail to survive unless artificially cultured because of failure of endosperm development.

Numerous investigations have been made on the basic cause of incompatibility. These have shown that hereditary factors are commonly involved: the plant chromosomes carry genes that control compatibility or unfruitfulness. The incompatibility factors are variable in type. Sterility results only when similar types are brought together in hybridization. Thus, if a plant carries a factor or factors for incompatibility, the same factors occur in both pollen and female reproductive parts and incompatibility results from attempted self-fertilization. Or incompatibility will result if this same plant is crossed with other varieties or species that carry the same incompatibility factors. Fruitfulness will result if the other variety or species lacks the factor for incompatibility or if the incompatibility factors are present but different in type. Similarly, a plant lacking in the sterility or incompatibility factor will be fruitful when self-pollinated if proper conditions are provided.

The subject of incompatibility is a complex one and is far from being completely understood. Enzymatic disturbances, differences in chromosome numbers and types, or chemical and mechanical alterations or differences may be involved.

Of primary importance to the plant propagator are the facts that incompatibility is common among the flowering plants and that the degree of expression of incompatibility varies both within and between species. Self-incompatibility has been estimated to occur in over 3,000 species and 20 families of plants. Also of primary importance to this group is the fact that no satisfactory method has been found for predicting these incompatible relationships. Experience is the only method by which they can be determined.

Several hybridization techniques have proved useful in overcoming incompatibilities. In some cases where the gametes are functional but incompatibility prevents pollen germination or pollen tube penetration of the stigma, removal of the incompatible surface of the stigma with a sharp razor-blade and pollination of the cut surface has resulted in successful seed production.

In some cases of incompatibility in which growth of the pollen tube is retarded in the style, seed production has been obtained by "bud" pollination. This involves opening the buds and applying pollen to the immature stigma. The time thus gained between application of pollen and normal deterioration and abscission of flowers sometimes allows the slower growing pollen tube to reach the ovules and effect fertilization.

Lewis (9) reports that, in general, use of growth hormones has failed to decrease incompatibility and increase viable seed set. However, Emsweller and Stuart (6) obtained seed set in incompatible crosses of *Lilium longiflorum* by use of 1% naphthalene acetamide at the time of pollination. The hormone was effective when applied at the base of the ovary, at a wound made by breaking or removing a petal. The treatment delayed abscission and stimulated growth. The commercially available "fruit set" hormones may be useful in this respect.

If apparently mature embryos develop but failures occur at the time of germination, dissection and removal of the embryo and its incubation on synthetic culture media may give successful seedling production. Considerable success has been achieved in the culturing of dissected plant tissues in artificial media (13, 14) and further trials with this technique would be of value. Attempted artificial culturing of immature female reproductive parts and pollination under such controlled conditions might be a useful technique in some difficult hybridization problems.

Incompatibility and Graftage

The problem of incompatibility as it concerns budding and grafting was recognized centuries ago. Chang (4) cites a Chinese publication in the year A.D. 500, which states that the pear *Pyrus serotina* is best suited on *Pyrus phaeocarpa* and that, in peach-plum combinations, the plum can be successfully grafted on peach whereas the peach usually fails to grow on plum stocks. A general rule or conception is that incompatibility can be expected in attempted combinations between taxonomically unrelated plants and that related plants, and especially ones of very close relationship, can be combined into a satisfactory composite plant without difficulty. Although this conception seems to offer the best basis for trial in new combinations, experience has demonstrated that this concept is not always reliable. Successful graft combinations have been made of commercial citrus varieties on trifoliate orange (*Citrus* sp. x *Poncirus*), lilac on privet (*Syringa* x *Ligustrum*), English walnut on Chinese wingnut (*Juglans* x *Pterocarya*) and many others that are not considered to be closely related. On the other hand, unsuccessful grafting results are frequently obtained from attempted combination of closely related plants, incompatibility occurring between varieties or strains of the same species. A few of the many examples that might be given concern the apple, pear, plum, grape, chestnut, white pine and holly. Heppner and McCallum (8) report that all varieties of peaches seem to show a strong affinity for both almond and apricot stock but apricots of all varieties seem to be a failure on almond. Adding further confusion to attempted prediction of successful graft combinations are reports in which two varieties have proved to be highly successful in one combination but their reciprocal combination has been highly incompatible.

Symptoms of inherent incompatibility in acute cases are failure of stock to unite with the bud or scion. In less acute to chronic cases, the bud or scion may unite with the stock but the bud may remain inactive, or bud or scion growth may occur with varying degrees of vigor only to decline and die after a few weeks, months, or years. In addition, the wide range of chronic or delayed incompatibility symptoms may include the common swelling or fracturing at the point of union, dwarfing of root or top, windthrow, a reduction in quantity and quality of fruit, and changes in resistance to climatic conditions.

A number of reports have been published concerning the growth aspects involved in graft incompatibility and theories concerning their cause. Since wounding and healing are the basic processes involved in graft union, healing and growth processes involved in recovery from different types of wounds have been studied and compared with those occurring in incompatible grafts.

Crafts (5), in a study of graft unions in *Nicotiana,* found that following wounding callus tissue was formed from the parenchyma of pith, phloem, xylem and cortex. This parenchymatous tissue is the first tissue to become united. Vascular strands were differentiated from the callus parenchyma and connected stock and scion within five days. Cambium arose within these strands and by lateral extension a complete continuous layer was formed to bridge the cambium of stock and scion.

Bradford and Sitton (3) reported that in simple wounds or those involved in compatible grafts, parenchymatous or callus tissue is formed first and becomes united by the intermingling or interlocking of cells at the interface. Tracheids, vessels and fibers appear in the bridge of parenchymatous tissue and soon establish continuity with those of stock and scion. If the fit of stock and scion is close, the parenchymatous zone is of limited extent and gradually disappears. The presence of parenchyma in the graft union was not found to be a sign of a weak or incompatible union unless the amount was excessive and union of callus or development of other tissues was arrested. The exactness of fit between stock and scion was found to be the chief factor underlying the union process but, within certain limits, the troubles arising from poor fit were gradually overcome.

Bradford and Sitton (3) also studied incompatible bud and cleft grafts of pear on apple and pear on quince in an attempt to determine the underlying processes involved in decline from incompatible unions. In some cases involving budding, good union occurred at the margins of the bud shield but there was no union, even of parenchymatous tissue from scion and stock, under the shield. This may explain why some buds fail to develop into active vegetative growth although good union appears to have been obtained. The incompatible reactions of bud and cleft grafts were similar, varying primarily in degree of intensity. In general, good union occurred at first, the interfaces being bridged by parenchymatous and vascular tissue. Later, breaks between scion and stock occurred along the line of union. New growth sometimes produced a rebridging of these breaks, amounting to a series of regrafts. Separations continued to occur with less frequent rebridging, tending to produce a more or less continuous line of separation. Tissues were distorted and cambium and vascular continuity was broken. Failure of continuity was often even more pronounced in the bark than in the wood.

Armstrong and Brison (2) have reported similar observations in a report on delayed incompatibility of a live oak-post oak graft union in which live oak scions were set by cleft grafts into two-inch limbs. Only one of four attempted grafts grew but this one made apparently normal growth for sixteen years. Between sixteen and nineteen years, the live oak top declined rapidly and a detailed examination was made of the union. Breaks began to occur at the union between stock and scion about 6 or 7 years after the graft had been applied. Some separations reunited as growth continued but the process did not occur readily and finally the graft union was girdled despite close contact and even alignment of cambial layers. There was no evidence of abnormal swelling at the union, and a point of interest to plant propagators should be that sixteen years passed before there were any visible external signs of deterioration from this incompatible union. Moreover, this case is not unique; graft failure on chestnut and walnut has occurred twenty or more years from the time of grafting.

Chang (4), in his study of incompatible unions of pear, apple, quince, plum, peach and cherry, found that separations between stock and scion may develop in either the bark or the wood or in both the bark and the wood. Similar observations have been made by other workers to support one definition of incompatibility as the failure to maintain cambium and therefore conductive continuity. However, in cases of acute incompatibility in which initial union is weak or fails to develop, lack of affinity or antagonism between parenchymatous or callus tissue of scion and stock seems to be involved prior to any initiation of true cambium or vascular tissue.

The possible varied mechanisms involved in incompatibility reactions other than complete failure and death of vegetative growth are more elusive and difficult to determine. A number of reports have been made of the effect of varied rootstocks on clonal scions. For example, variation in rootstocks have been reported to have a pronounced effect on pollen fertility of citrus scions, on mineral content of fruit and foliage of tung and citrus, on shedding of flowers and fruit of persimmon, on susceptibility to disease, on vigor, and on other aspects of growth. Such variations, since they concerned clonal scions on varied rootstocks, may involve incompatibility.

The underlying or basic causes of graft incompatibility are still theoretical and primarily concern differences in physiological or anatomical characteristics of scion and stock. A lack of synchronization in growth processes may be a cause of graft separation and failure. Early cambium activity or tissue differentiation and expansion in one component of the graft union when the other component is dormant or more retarded may create breakage and planes of separation leading to structural weakness and disrupted translocation. This conception has led to several suggested means of determining possible compatible combinations. The suggestions have concerned comparison of the plants to be united in respect to the time of spring foliation, the time of spring cambial activity, or the differences in growth rates or curves. Such methods have not proved to be reliable in practice, and as in incompatibilities affecting sexual propagation, the only successful guide is actual experience. Other theories on causes of incompatibility concern differences between scion and stock in vigor, enzymes or hormones, protein specificity, permeability and the presence of toxins. Climatic conditions also have been suggested as playing a possible role in incompatibility since some graft combinations constantly failed or have proved to be unsatisfactory in some geographical areas but quite satisfactory in others. It is possible in this case and others, however, that factors other than inherent incompatibility are involved.

Needless to say all graft failures or unsatisfactory performance of composite plants during subsequent growth are not due to incompatibility. Suspected incompatibility in a number of fruit tree grafts was found by Bradford and Sitton (3) to be caused by mechanical faults in the grafting technique. In cleft and bark inlay grafts a common fault was insufficient pressure from the graft tie to prevent pushing apart of the stock and scion and consequent failure of the calli to unite. In bridge and cleft grafts the scion was frequently set too deep, the bark of the scion preventing union between scion and the top of the stock. Swelling and abnormal growth at the union were not signs of incompatibility; the most uncongenial combinations produced no swelling. Swelling was frequently caused by poor fit, by failure to remove the graft tie when of material that did not deteriorate to prevent girdling, and by setting the scion in cleft grafts at an excessive outward tilt. In the last, union occurred only at the base of the scion and none at the upper rim of the stock which resulted in swelling and failure to heal over the stub. Tilting of the scion in an attempt to obtain cambium contact between scion and stock is not a good practice, the most important consideration in cleft grafts is to secure good cambial alignment at the top of the stock.

Several reported or suspected cases of incompatibility have been proved upon further investigation to be caused by infectious diseases U.S.D.A. 227, an apple rootstock of Northern Spy origin, was reported from several sources as being incompatible with a number of apple varieties. Weeks (12) and Gardner, Marth, and Magness (7) demonstrated, however, that the suspected incompatibility was due to a virus. The virus was nonlethal to most apple varieties but lethal to this rootstock. Apparent cases of incompatibility were produced when virus-carrying scions were placed on the susceptible rootstock. Tristeza or quick decline of citrus is another and similar example of pseudo-incompatibility produced by virus infection (11). The disease appears when sweet orange and certain other virus-carrying but tolerant citrus varieties are grafted on the sour orange, which is susceptible.

Means by which incompatibility between scion and stock of a desired combination may be overcome involves "double working." Bridging the desired scion and stock with an intermediate piece consisting of a variety that is compatible with both is a common practice. Although the practice is commonly used, it is questionable whether adequate consideration is always given to the influence of the intermediate piece on scion or rootstock and the diverse delayed incompatibility reactions that may be produced. The other alternative in propagating highly and generally incompatible material is the production of own-rooted stock from vegetative cuttings. In this connection, the incompatible "nurse-root" method for obtaining own-rooted plants should be mentioned. Material that is difficult to root is sometimes grafted to an incompatible root-piece and then planted rather deeply in the rooting material. The incompatible root-piece provides sufficient temporary support to the scion for scion roots to be produced before the graft union deteriorates.

Conclusion

Despite the possible confusion engendered by this presentation on the subject of incompatibility, some of its aspects and implications are worthy of emphasis. The plant propagator should be constantly aware that incompatibilities do exist and may seriously affect attempted propagation by either sexual or asexual methods. These adverse effects may be immediate or delayed for weeks, months, or a considerable number of years.

The immediate effects are probably of least concern since they are pronounced and occur in the plant propagator's domain. The craftsmanship of the propagator is immediately challenged, either by the problem itself or by the propagator's employer, and a serious effort is usually made to determine the cause of failure and methods by which it may be overcome. On the other hand, the delayed failures or unsatisfactory performance of the finished stock at some period during utilization may receive little or ineffectual attention. The latter should be of equal concern to the plant propagator and the sphere of his interest should not end with the production of lining-out stock or even attractive, vigorous-appearing stock of saleable size.

Incompatibility may be the basic cause of varied types of propagation failure or unsatisfactory plant performance. However, it is but one possible cause and it should not be ignored or overemphasized when propagation problems arise. The propagator's skill, knowledge and initiative are also involved

Compatible combinations in hybridizing and graftage can be predicted only on the basis of experience. But relatively little guidance is provided by any one textbook or other publication to insure compatible relationships. Many successful and unsuccessful experiences have not been recorded and the best source of information concerning a specific problem may be through the free discussion and exchange of information which has been made a requirement for membership in your Plant Propagators Society.

LITERATURE CITED

1. ARGLES, G. K. 1937. A review of the literature on stock-scion incompatibility in fruit trees, with particular reference to pome and stone fruits. *Imp Bur. Fruit Prod , East Malling, Tech. Commun* 9: 5-115.
2. ARMSTRONG, W. D. and F R. BRISON. 1949. Delayed incompatibility of a live oak-post oak graft union. *Proc. Amer. Soc. Hort. Sci* 53:543-545.
3. BRADFORD, F. C. and B. G. SITTON. 1929. Defective graft unions in the apple and the pear. *Mich. Agr. Expt Sta. Tech Bull* 99.
4. CHANG, W. T. 1938. Studies in incompatibility between stock and scion, with special reference to certain deciduous fruit trees. *Jour. Pomol. and Hort. Sci.* 15: 267-325.

5. CRAFTS, A. S. 1934. Phloem anatomy in two species of *Nicotiana*, with notes on the interspecific graft union. *Bot. Gaz.* 95: 592-608.

6. EMSWELLER, S L. and N. W. STUART. 1948. Use of growth regulating substances to overcome incompatibilities in *Lilium*. *Proc. Amer. Soc. Hort. Sci.* 51: 581-589.

7. GARDNER, F. E., P. C. MARTH and J. R MAGNESS. 1946. Lethal effects of certain apple scions on Spy 227 stock. *Proc Am. Soc. Hort. Sci.* 48: 195-199.

8. HEPPNER, M. J. and R. D. McCALLUM. 1927. Compatible and non-compatible graft unions. *Proc. Am. Hort. Sci.* 24: 137-138.

9. LEWIS, D. 1949. Incompatibility in flowering plants. *Biol. Rev.* 24: 472-496.

10. ROBERTS, R. H 1949. Theoretical aspects of graftage. *Bot. Rev.* 15: 423-463.

11. WEBBER, J. J. 1943. The "tristeza" disease of sour orange rootstock. *Proc. Am. Soc. Hort. Sci.* 43: 160-168.

12. WEEKS, W. D. 1948. Further scion and stock combinations with Spy 227. *Proc. Am. Soc. Hort. Sci.* 52: 137-140.

13. WHITE, P. R. 1943. A handbook of plant tissue culture. Jacques Cattel Press, Lancaster, Pennsylvania, 277 p.

14. WHITE, P. R. 1946. Plant tissue culture II. *Bot. Rev.* 12: 521-529.

* * * *

PRESIDENT WELLS: Thank you very much, Roger, for the excellent discussion of the role of Compatibility in Plant Propagation. Following the established custom of our meetings, we are now ready for questions on Roger Swingle's paper.

MR. RICHARD H. FILLMORE (Lakes Shenandoah Nurseries, Shenandoah, Iowa): Do you favor Robert's more broad concept of incompatibility or the concept of Bradford and Sitton, and others?

MR. SWINGLE: Personally I prefer the broader concept. In some cases, the only effect of incompatibility is plant sterility. To the plant hybridizer, sterility is as serious a problem as graft breakage or other types of failure.

PRESIDENT WELLS. In connection with the comments about the pressure necessary to insure a good union, which I believe concerned the grafting of fruit trees, how important is it in the more detailed grafting of conifers or the smaller material that many of us work with in greenhouses?

MR. SWINGLE: I think it is of utmost importance. Of course, the point I wished to make was that all failures are not due to incompatibility. In this case, graft failure was due to faults in grafting technique and not due to incompatibility. I know in our own narrow field of propagation one of our troubles has been in getting the men to make the proper tie. In the budding procedure, if the tips of the bud shield are not covered or crossed by the tie a high percentage of failures result. I think it is very important on all types of grafts. Also, it is important to examine the grafted stock frequently and make sure the tie is removed at the proper time.

PRESIDENT WELLS: With regard to the question of materials used for tying, of which there seems to be a great number—budding strips, wax twine, adhesive tape, etc.—do you have any preference?

MR. SWINGLE: We prefer the rubber strips on small stock. However, we watch those very carefully because we have found you cannot depend on them to deteriorate at the proper time. On the other hand, for grafting large stock we use twine and create a lot of pressure at the graft. We get good grafts that way, whereas the grafts fail if we don't have sufficient pressure. The twine tie must be watched and cut to prevent injury from girdling.

MR JAMES ILGENFRITZ (Ilgenfritz Nurseries, Inc., Monroe, Michigan): I understand the propagation of fruit trees by grafting and budding is probably 400 years old, more or less. Throughout this period has there been any compilation of compatibility information having to do with varieties of fruit trees and various kinds of stocks, particularly the Malling stocks?

MR. SWINGLE: There is information scattered throughout the literature. The best compilation I have found is in the article by Argles that I have cited in the paper that has been presented. It is primarily on the different fruit varieties. When you get into miscellaneous nursery stock, I don't know of any place to go for that.

DR. W. E. SNYDER (Cornell University, Ithaca, N.Y.): There is a classical example of incompatibility caused by faulty grafting of a coniferous tree from Norwich, New York. The tree reached a height of about 25 feet. One morning the cemetery caretaker noticed that the tree was down. It looked like vandalism because the place of severance was as smooth as a table top, however, there was no sawdust around. A detailed examination showed, first, that incompatibility existed; second, that the cut had been made three-fourths of the way through the understock, and third, that the graft was not tied tightly. Thus, incompatibility and faulty technique can sometimes be determined as much as 25 years after you have done the work.

PRESIDENT WELLS: I have one or two other questions. The first one is: Is it serious if in the course of the union of stock and scion external material, such as bark, is enclosed in the callus tissue which may cover the wound? The second one is: Has any work been done in the treating of scions by any of the hormones to overcome incompatibility, if incompatibility in this instance might be due to faulty union of the tissues?

MR. SWINGLE: Concerning the first question, foreign material between the graft inner faces might prevent close contact of the faces. The closer contact you have between faces, the better chance you have of good union. Also, if foreign materials are present, you open up the possibility of disease conditions developing. We always try to get as clean a surface as we possibly can.

On the use of materials to overcome incompatibility, I don't know of any work that has been done along that line, at least with any success. I believe some work has been done with some of the growth hormones to try to stimulate healing. I don't believe they have worked out satisfactorily—not to my knowledge, anyway.

MR. JACK HILL (D. Hill Nursery, Dundee, Ill.): I wonder about this question of removal of the tie in the case of conifer grafts. Just when do you determine the optimum time for removing the tie, whether it be one of rubber grafting strip, of waxed twine, or tape?

MR. SWINGLE: When is the optimum time to remove the tie? I can't answer that. We try to watch the grafts carefully for compression of bark under the tie. If there is any evidence of the tie starting to girdle, we cut the tie. If a good union has not occurred, the graft is retied. We may do that two or three times, especially where we are grafting large stock and using heavy twine.

MR. MARTIN VAN HOF (Rhode Island Nursery, Newport, R. I.): I would like to ask about Malling stock No. IX. Can you give me any information on its compatibility with all varieties of apple?

MR. SWINGLE. I think that No. IX has been incompatible with certain combinations but somebody else may be better able to answer that question than I am. Dr. Chadwick may know more about it.

DR. L. C. CHADWICK (Ohio State University, Columbus, Ohio): I don't know that I have the answer to that question but this point might be mentioned. Talking with some of the men at the East Malling Station a little over a year ago, they wouldn't admit that there was any incompatibility with Malling No. IX. They claim the dwarfing is due to other factors and not incompatibility. I think some question could be raised about their interpretation about that, however, as it has been shown that you do get dwarfing as a result of incompatibility. Some recent work has indicated that the length of the Malling IX piece, if it is used as intermediate stem piece, influences the degree of dwarfing. In other words, if you used a 6-inch piece, you would get more dwarfing than if you used a two-inch piece of Malling IX.

MR. VAN HOF: You mean to say to plant your union above the ground?

DR. CHADWICK: In this case, that is right. The comment, of course, was on the use of Malling IX in the stem piece, which would be above the ground.

MR. VAN HOF: In reference to a slow-growing variety, would it be advisable to graft them on a more vigorous understock—Malling No. VII, for example?

DR. CHADWICK: If I get your interpretation right, you are thinking of increasing vigor on slow-growing varieties? I think, yes, it would definitely be true that you would get more vigorous top produced on a Malling VII than on Malling IX.

MR. VAN HOF. Would it lose dwarfing?

DR. CHADWICK: Different Malling stocks produce various degrees of dwarfing. Malling VII will not give you as intensive a dwarfing as No. IX.

MR. A. M. SHAMMARELLO (South Euclid, Ohio): I would like to ask is it compatibility or incompatibility when a lilac grafted on privet won't grow on its own roots? For instance, we have difficulty with white lilacs.

MR. SWINGLE: I wouldn't say that this is a case of incompatibility. I can see the possibility that incompatibility might influence rooting of a scion, but I would question whether incompatibility is concerned in this case. In our propagation work, cuttings of certain elm selections or strains have failed to root. We don't know why and have covered up our ignorance by saying they are inherently difficult to root. Factors other than incompatibility are probably involved. Can you root the lilac any other way?

MR. SHAMMARELLO: Yes, you can root them by soft-wood cuttings, but we usually graft on privet. The blue and purple varieties immediately succer and root. The white ones make a big knob at the base and they don't grow on their own roots.

MR. SWINGLE: I doubt that incompatibility is concerned. I, personally, would suspect some other condition.

MR. HARVEY GRAY (Long Island Agricultural Technical Institute, Farmingdale, N. Y.): I would like to raise the question relative to this business of tying. It has been my observation that wax twine is often bound so that there is no space between one cord and the next. There seems to be some conviction that if there is a slight space between one strand and the next the union develops more readily than with the tight construction. I wonder if that is an observation of Mr. Swingle?

MR. SWINGLE: I haven't made any specific observations along that line. A number of years ago it was common to wax over the ties and I think it may have been a bad practice. Possibly oxygen relationships are involved. We get much poorer results than if we don't use wax and exclude the air. This was primarily on elm propagation. It may vary with different plants.

PRESIDENT WELLS: If there are no other questions at this time, I think we should proceed to the next part of the program. There will be opportunity to ask further questions of Roger during some of the open sessions.

At this time, I would like to ask Bill Snyder to tell us about the Plant

Propagation Question Box which he has arranged for the session for Friday night.

DR. SNYDER: Since it is quite probable that there will not be sufficient time for all of the speaker-exhibitors this afternoon, this evening's session will be used to complete this section of our meetings. The exhibits will be displayed during the entire meeting so that each of you will have an opportunity to examine them at your convenience.

Last year I spent considerable time asking various members about germination and growth of a particular plant. I am certain that many of you did the same. This year, for the first time, there has been arranged a special session at which specific questions, not concerned with the topics to be covered in the various round-tables, can be asked. This session has been called the Plant Propagator's Question Box and is scheduled for Friday evening. If you have questions about plant propagation which you want answered, write the question on a card and place it in the Question Box at the rear of the room. Ask any question about propagation you want, except those relating to the panel topics. If you desire a specific person to answer the question, indicate this on the card also. The success of the Question Box requires your cooperation both by submitting the question and by being present to answer the questions of other members.

PRESIDENT WELLS: Thank you, Bill. Let's fill the box with good questions.

We now come to something new. Last year, as always when a group of plant men get together, a few people brought along some plants tucked underneath the bed in their room and people went around looking at them. We realized then that we should organize and direct that interest with proper exhibits and brief discussions Dick Fillmore was asked to organize a speaker-exhibitor session. Those of you who know Dick will realize how careful and methodical he is in work of this kind. From what we see around the room, the choice of Dick was an excellent one. Without more ado, I will turn the meeting over to him.

Mr. Richard H. Fillmore took the chair.

CHAIRMAN FILLMORE: It certainly has been a pleasure during the past several months to correspond with the large group of persons who have furnished exhibit materials for this meeting.

We are going to have ten speaker-exhibitors, each of whom will briefly discuss his exhibit. In addition, there are some twelve or fifteen persons who have set up other exhibits. You may, of course, ask questions concerning them, both directly to the persons who set up the exhibits and indirectly during one of the question periods which have been provided during the meeting.

We probably won't have time to finish the group of ten speaker-exhibitors this afternoon, but those who do not have an opportunity to speak this afternoon will speak this evening. In general, we are going to allow twelve minutes for each speaker-exhibitor: a couple of minutes for an introduction, about seven minutes for the discussion, and two or three minutes for questions. We should like to keep this session exactly on time.

The first discussion is concerned with budding. The first speaker is Mr. William Flemer of the Princeton Nurseries, Princeton, N. J. Mr. Flemer is a graduate of Yale University and, together with his father and brothers, is associated with one of the finest ornamental nurseries in the United States. Mr. Flemer will speak on the propagation of the American elm by budding.

MR. WILLIAM FLEMER, III: Thank you, Mr. Fillmore, and good afternoon.

Before I start the discussion of budding American elm, I should like to comment briefly on the question of compatibility. May I ask the committee which prepares our Proceedings whether it wouldn't be a good idea to have perhaps one sheet in the back of the Proceedings on which experimentally-minded growers might record their experiences with compatibility of understocks? I am thinking that we could set up a simple table in which there would be, for instance, a column for the scion, a column for the understock, and a column for a simple numerical key to indicate the degree of success for the particular graft. As a suggestion, the key might be. A for satisfactory growth; B, grows for a couple of years and then dies, C, grows briefly; and D, no evidence of a successful union. I think such a table might save a lot of experimentally-minded propagators from wasting time and effort and at some future date the information could be consolidated for the use of the members.

I might cite three examples in my own experience during the past five years. One is an attempt I made to bud Paul's Scarlet hawthorn on *Crataegus cordata* understock (Washington thorn), in which we got wonderful growth the first year, but signs of incompatibility the second year. During the third year, the trees reached a height of about five or six feet and died. Two other attempts were concerned with trying to find a better understock for the Japanese maple (*Acer palmatum*). We found that when *A. ginnala* and *A. buergerianum* were used as the understock, the scions grew actively for periods up to a month and then suddenly languished and died.

Mr. Flemer discussed the budding of the American elm. (Applause)

Budding the American Elm

WILLIAM FLEMER III
Princeton Nurseries, Princeton, New Jersey

Propagating American elms would seem, with the diseases which we have around, like propagating American chestnut from seed, but we at Princeton Nurseries haven't viewed it in that way. We have continued to grow elms and we have found that while we don't grow 40,000 or so annually as we used to do, we still grow between three and four thousand introduction, about seven minutes for the discussion, and two or three minutes for questions. We should like to keep this session exactly on time.

The first discussion is concerned with budding. The first speaker is Mr. William Flemer of the Princeton Nurseries, Princeton, N. J. Mr. Flemer is a graduate of Yale University and, together with his father and brothers, is associated with one of the finest ornamental nurseries in the United States. Mr. Flemer will speak on the propagation of the American elm by budding.

MR. WILLIAM FLEMER, III: Thank you, Mr. Fillmore, and good afternoon.

Before I start the discussion of budding American elm, I should like to comment briefly on the question of compatibility. May I ask the committee which prepares our Proceedings whether it wouldn't be a good idea to have perhaps one sheet in the back of the Proceedings on which experimentally-minded growers might record their experiences with compatibility of understocks? I am thinking that we could set up a simple table in which there would be, for instance, a column for the scion, a column for the understock, and a column for a simple numerical key to indicate the degree of success for the particular graft. As a suggestion, the key might be. A for satisfactory growth; B, grows for a couple of years and then dies, C, grows briefly; and D, no evidence of a successful union. I think such a table might save a lot of experimentally-minded propagators from wasting time and effort and at some future date the information could be consolidated for the use of the members.

I might cite three examples in my own experience during the past five years. One is an attempt I made to bud Paul's Scarlet hawthorn on *Crataegus cordata* understock (Washington thorn), in which we got wonderful growth the first year, but signs of incompatibility the second year. During the third year, the trees reached a height of about five or six feet and died. Two other attempts were concerned with trying to find a better understock for the Japanese maple (*Acer palmatum*). We found that when *A. ginnala* and *A. buergerianum* were used as the understock, the scions grew actively for periods up to a month and then suddenly languished and died.

Mr. Flemer discussed the budding of the American elm. (Applause)

Budding the American Elm

William Flemer III
Princeton Nurseries, Princeton, New Jersey

Propagating American elms would seem, with the diseases which we have around, like propagating American chestnut from seed, but we at Princeton Nurseries haven't viewed it in that way. We have continued to grow elms and we have found that while we don't grow 40,000 or so annually as we used to do, we still grow between three and four thousand a year. We find that there is again beginning to be a moderate interest in planting American elms.

I think that at least in the East, where we have had Dutch elm disease for a number of years, there are still plenty of elms around. At least in rural areas there are still good reasons for planting the American elm.

A number of years ago when we first started to grow American elms in my grandfather's F and F Nursery in Springfield, it was found that the American elm was one of the most variable of all shade trees. Some seedlings grew up rapidly into tall, graceful trees, while others were slow growing. There was a variation in the susceptibility to insects, such as the aphids which curled the leaves, and a great variability in winter hardiness.

At that time we instituted a program of selecting American elm seedlings from the seedling blocks. Over a number of years we have gradually narrowed the selections down to one type which has been named the "Princeton Elm." It is a rapid growing, large-leaf, selection with rather glossy foliage. In this day and age we still grow some Moline elms and we propagate Christine Buisman by propagating on some kind of understock.

Propagation of our elm understock begins with collecting seed which matures in late May or early June in our section of the country. We sow the seed in three-foot nursery rows. The seed are covered with sand and germination takes place within a week or two. The seedlings are grown for two years in the seedling row and are about pencil size in diameter. They are dug, graded, and planted in eight-foot rows with two feet between plants. Since they grow one season in the field before budding, the understock is three-years old when they are budded.

We undertake to bud the elm seedlings on the 15th day of August, weather permitting, or not later than the 20th. Our bud sticks are selected from young nursery-grown plants and we try to get as large a bud stick as we possibly can. We use only the buds from the middle third of the stick. Buds from the bottom of the stick are too small in relation to the bark and those from the upper third are too large in relation to the shield which must be used.

The buds peel very easily and we use a peeled bud just as in apple budding. We tie them with rubber budding strips. The strips are cut at the end of two weeks by which time union has taken place.

The top of the understock is cut off the following winter in February or sometimes in early March. The bud breaks into rapid growth in the spring. The new shoot is staked immediately with a short supporting stake to prevent it from blowing over until the shoot becomes woody.

We have found one problem. For some reason, rabbits seem to prefer the varietal buds to the naturals which arise from the understock. Possibly this is because of a higher sugar content. We are very careful to keep all rabbits out of the bud block until the new shoots have reached three feet in height. Rabbits do not seem to harm the plants after they have reached this size.

* * * *

CHAIRMAN FILLMORE: Thank you very much, Mr. Flemer. You have presented the budding procedure used by the Princeton Nurseries for the American elm in a very interesting manner, and you have also set a good precedent by allowing ample time for questions.

MR. ILGENFRITZ: Will you comment on the relative growth rate of budded American elm compared with seedlings which are cut back and allowed to grow by themselves?

MR. FLEMER: One of the main criteria we used when selecting the strains of American elm which we bud was vigorous growth One-year buds at the end of a full growing season will average between six and eight feet in height and up to ¾ inch in diameter. It is a rare seedling, indeed, that is that tall or that thick I would say that on the average our budded elms are twice the size of naturals which develop on seedlings on which the bud did not take.

MR CARL G. WILSON (Thompson Products, Euclid, Ohio). Do you consider Dutch elm disease curable?

MR. FLEMER: I don't think the Dutch elm disease is curable, but I think that as the population of elms is reduced and, therefore the elm bark beetle is also reduced, that the incidence of the beetles and hence the incidence of the disease is bound to be reduced too. I don't think that we should plant long avenues of elms because through root grafts and the presence of a large population there is no question but that Dutch elm disease will occur. I still think, however, that there is plenty of room for individual specimens scattered through-out the community, to grow and thrive despite the prevalence of the disease. Dutch elm disease is not wind carried like the chestnut blight. It has to be carried by the insect and the insect is controllable by spraying. I don't think we should go into a large program of elm planting, but I don't think we should give them up entirely.

* * * *

CHAIRMAN FILLMORE: When I wrote Mr. John Siebenthaler concerning speaking at this meeting, he replied that there was some likelihood he could not come because of the large amount of travel involved in his duties as president of the American Association of Nurserymen, but I wonder if Mr. Jack Siebenthaler, The Siebenthaler Co., Dayton, Ohio, will discuss the subject of the propagation of honey locust by summer budding.

MR. JACK SIEBENTHALER: I wasn't expecting this, Dick, but I will be glad to offer what I can. Many of you gentlemen are probably familiar with our practices on the Moraine locust which is what I will discuss.

The Propagation of Honey Locust by Summer Budding

Jack Siebenthaler
The Siebenthaler Co , Dayton, Ohio

We select our seed in the fall when the pods are ripe and beginning to fall. We have no established practice for selection of seeds. We do secure a large number of seed each year and, as was the case this year, many of the seeds are not good. We try to get enough good seed so that we will have an ample supply of our own seedlings. We have found that we get the quickest cleaning by running the seed through a mascerator.

We sow the seed either in the fall or early spring. We have done it at both times and with good success either way. I think fall sowing in our particular location is satisfactory

We dig the seedlings in the fall after one year of growth and store them over-winter outside. We don't attempt to store them in controlled refrigerated storage. We heel-in the seedlings in sand so they are readily available for spring planting. We grade them before heeling them in so that there will not be added delay when planting time arrives. The seedlings are planted in the early spring and, weather permitting, we like to get them in the ground by mid-April. They are budded about the last week in June or the first week in July. That seems to be a little earlier than some people bud, however that is the time we have found to be optimum for our particular locality.

We de-wood the buds before inserting them and we use rubber strips for tying. We usually manage to get all of the budding done in ten to fourteen days, so there isn't too much of a time lapse. We get a good percentage.

Most of the buds do not begin to grow until the following spring; however a certain percentage of them do. We haven't found that this is detrimental. There have been times when some of those first buds are injured by a severe early freeze, or some similar circumstance. Like the American elm budding practice, we cut off the tops in the early spring, usually in the middle of March.

As the bud begins to grow we stake as soon as possible. The two reasons for early staking are, first, we like to get the stakes into the ground when the ground is soft enough for easy insertion, and, secondly, we like to begin tying the bud to the stake when it is not much over fifteen inches tall.

In the course of the summer's growth of the budded Moraine locust, we will tie them four to six times, depending on the individual shoot. They grow to eight feet or slightly more. The average growth is about seven feet and some side branches develop

We trim these lateral buds as part of the summer maintenance. The time of trimming usually is August or the early part of September The only thing we do is to trim off side branches which develop within four feet of the ground.

Just as an aside and something which may possibly be of interest to some of you, we leave the multiple buds. Out of a block of plants, we get fifteen to thirty that are unusual. The natural tendency has been to consider these as freaks and unwanted. However, since we are in the landscape business, we like to have something a little different to offer our customers.

Quarter inch iron rods are preferred for tying. We like them because they last indefinitely. The rust on them doesn't seem to make any difference. Considering the breakage of bamboo poles, especially if the ground is hard, I think we are ahead by using the iron rods. However, we don't have enough iron rods and are forced to use a few bamboo stakes.

We dug the locust rather early this year. We had them all out of the ground before the first of November, but that isn't always the case. Last year, it was a little bit later. However, we experienced two straight seasons of particularly dry weather and the ground was particularly hard. Last year, we didn't have facilities to water at the right time to make digging easier. This year we had the facilities to water and consequently dug earlier. The leaves were still on the trees but they defoliated when we started to handle them.

Again, storage is outside and we heel the trees in sand. They are graded as soon as dug and are tied into bundles containing definite numbers.

* * * *

CHAIRMAN FILLMORE: Thank you very much, Jack. There is time for only one question.

MR. BLYTHE (McConnel Nursery, Port Burwell, Ontario): The new growth is very soft in June and July. Were the buds taken from two-year or one-year wood?

MR. SIEBENTHALER: One year. The wood evidently is a little harder in our area than in your locality.

* * * *

CHAIRMAN FILLMORE: Fellow-members and guests. I am happy to present, on behalf of Mr. Peter Nicolin, of Frauweiler b. Koln, West Germany, an exhibit of the Nicolieren budding method as developed by him. This method was developed to overcome incompatibility between certain varieties of pears and quince.

Such incompatibility is usually overcome by first budding or grafting, on a quince understock, a variety of pear which is compatible both with the quince and with the desired variety. Upon this doubly compatible pear, one later buds or grafts the desired pear variety. Herr Nicolin has reduced this expensive and time consuming procedure to a single operation by inserting a thin slice of the compatible variety under the varietal bud. This is one of the most ingenious propagating methods which has ever been brought to my attention.

The Nicolin Exhibit consists of the following bud-graft combinations:

1. Amsden plum on Brompton with Mandel Nicolier-intershield
2. Kostliche aus Charneu pear on quince with Pastoren pear Nicolier-intershield
3. Clapps Liebling pear on quince with Pastoren pear Nicolier-intershield
4. Williams Christbirne pear on quince with Neue Poiteau pear Nicolier-intershield
5. Schoner aus Boskoop apple on Malling II with Mallıng IX Nicolier-intershield

May I express to Mr. Nicolin my deepest personal appreciation for his generosity in sending us this outstanding exhibit. May I also translate the concluding paragraph from his accompanying letter, "I wish this package to reach you ın good time, a good outcome of your day and may this exhibit "rise high" as a friendly greeting of one of the German nurserymen. With friendly greetings. Peter Nicolin."

Chairman Fillmore read a translation of the paper of Peter Nicolin which described the budding technique. (Applause)

Nicolieren, a New Method of Grafting*

P. Nicolin
Frauweiler b. Koln, West Germany

When my good old bearded teacher taught me grafting in the year 1911, I tried my luck with a twenty-year old apple tree.

I was not satisfied, however, with just a single kind, so six different ones were grafted: Teasgoods, Borsdorfer, Cellini, Gravenstein, Sternrenette and Goldparmane.

And they really all adhered!

Who could not imagine the joy and the pride of an eleven year old after such a success!

After this event, I have always kept in touch with trees and nurseries; I have tried many things, and now and then have been rewarded with good results.

The year before last I suddenly had a strange thought as I deliberated about the incompatibility of many pears with their quince understocks and what to do about it.

Of course, one can remedy this by introducing a more compatible intermediate. This is an old trick.

But one loses a whole year of culture by so doing. How would it be if one could reduce the intermediate to a single slice and, together with the incompatible piece, place them into the budding opening? I grafted twenty quinces with Clapps "darling" (Liebling) and Williams Christ-

*English translatıon of original article from Deutsche Baumschue Vol 5, No 7 for July, 1953. By permission Herr Gerd Krussman, Editor.

1. Amsden plum on Brompton with Mandel Nicolier-intershield
2. Kostliche aus Charneu pear on quince with Pastoren pear Nicolier-intershield
3. Clapps Liebling pear on quince with Pastoren pear Nicolier-intershield
4. Williams Christbirne pear on quince with Neue Poiteau pear Nicolier-intershield
5. Schoner aus Boskoop apple on Malling II with Mallıng IX Nicolier-intershield

May I express to Mr. Nicolin my deepest personal appreciation for his generosity in sending us this outstanding exhibit. May I also translate the concluding paragraph from his accompanying letter, "I wish this package to reach you ın good time, a good outcome of your day and may this exhibit "rise high" as a friendly greeting of one of the German nurserymen. With friendly greetings. Peter Nicolin."

Chairman Fillmore read a translation of the paper of Peter Nicolin which described the budding technique. (Applause)

Nicolieren, a New Method of Grafting*

P. Nicolin

Frauweiler b. Koln, West Germany

When my good old bearded teacher taught me grafting in the year 1911, I tried my luck with a twenty-year old apple tree.

I was not satisfied, however, with just a single kind, so six different ones were grafted: Teasgoods, Borsdorfer, Cellini, Gravenstein, Sternrenette and Goldparmane.

And they really all adhered!

Who could not imagine the joy and the pride of an eleven year old after such a success!

After this event, I have always kept in touch with trees and nurseries; I have tried many things, and now and then have been rewarded with good results.

The year before last I suddenly had a strange thought as I deliberated about the incompatibility of many pears with their quince understocks and what to do about it.

Of course, one can remedy this by introducing a more compatible intermediate. This is an old trick.

But one loses a whole year of culture by so doing. How would it be if one could reduce the intermediate to a single slice and, together with the incompatible piece, place them into the budding opening? I grafted twenty quinces with Clapps "darling" (Liebling) and Williams Christ-

*English translation of original article from Deutsche Baumschue Vol 5, No 7 for July, 1953. By permission Herr Gerd Krussman, Editor.

birne pears and placed in between a thin slice of Gellert's "butterpear" (Butterbirne) and Pleiner Mostpear under the eyes.

All twenty graftings adhered normally and made normal yearlings, even though they were grown upon a completely "tree tired" piece of land which had been loaned by the Institute for Plant Diseases in Bonn.

These bud-grafts, which were made in the summer of 1952, did not disappoint me. Among the first 20 trial bud-grafts, I placed on one plant two intermediate slices under the varietal bud and all these adhered naturally, but of course, this was only play on my part.

This spring I have used an intermediate slice while whip grafting and I believe this will also be successful.

It would be interesting to know if a bridge of the "Wagenstadt Schnapsplum" would do away with the incompatibility between the "Lutzelsachser Early Plum" and Brompton. Science might begin with tests to find out about it.

We know for example that Cox on Malling IX produces highly colored fruit; on Malling II, the fruit is striped, and upon Malling XI, the fruit remains unattractively greenish.

One might also try to find out how the adding of my intershield affects the color and the size of the crop.

I have named my method "Nicolieren" and tried to have it patented.

Now I should like to explain the technique of my method.

One has in readiness two scions, one for the intershield (without leaves and leaf stems) and one for the desired variety.

One cuts a bud from the scion as is done in budding, this bud, however, is not used. Then one cuts from the scion another thin slice from the place where the bud was removed This makes a budless shield.

Now the Nicolier-intershield has the desired form. The slice should be about 1.5-2mm. thick (1 mm.—approx. 1/25 inch). It is then placed into the T-cut and then the bud of the incompatible sort is also placed into the cut It is not too difficult to place the cambium layers of the Nicolier-intershield and the varietal bud exactly upon one another.

It is advisable to do this kind of budding as early as possible and only with ripe wood. The placing of the Nicolier-intershield and the varietal bud must be done by hand.

It is advisable to bind tightly.

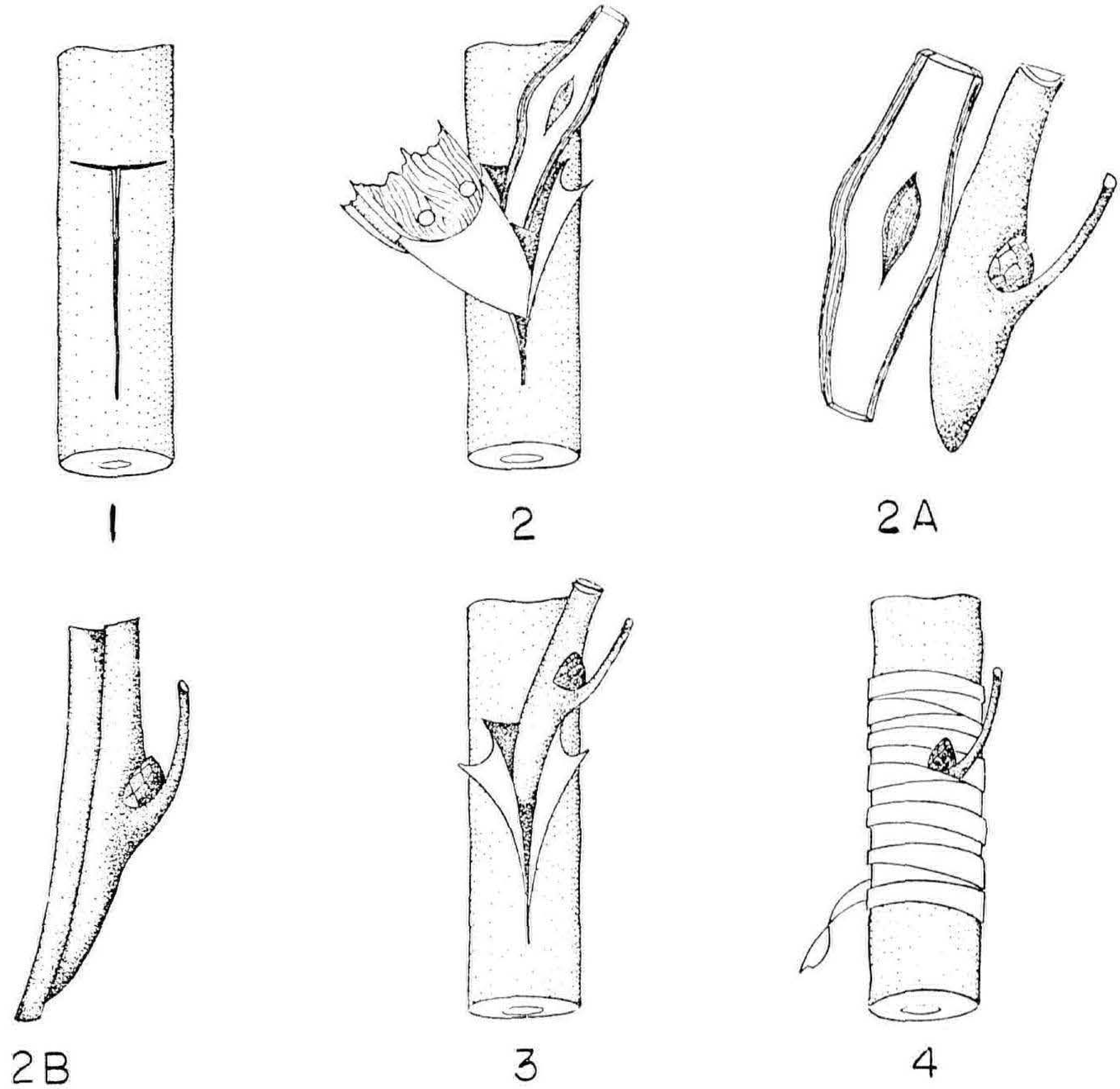
* * * *

(Editor's Note: A similar budding method has been described by Mr. R. J. Garner, East Malling Research Station, East Malling, England, in the following publications:

Garner, R. J. Double-working pears at budding time. Annual Report, East Malling Research Station for 1952:174-175 ———. Double-working to overcome incompatibility. The Fruit Yearbook 1954:1-5.)

CHAIRMAN FILLMORE: It is realized that it will take five to ten years to adequately test this method of budding. It does seem to be practicable and Mr. Nicolin has shown great ingenuity. I predict that this method is going to become important both experimentally and practically.

MR. LESLIE HANCOCK (Woodland Nurseries, Cooksville, Ontario): Mr. Chairman, this meeting should send a suitable message, either in the form of a wire or a letter acceptable to the Executive Committee, to Mr. Nicolin expressing the great appreciation of the Plant Propagators Society for the wonderful gesture he has made in freely sending this ma-



NICOLIEREN BUDDING TECHNIQUE

1. T-cut as in shield budding
2. Nicolier-intershield inserted in T-cut
3. Varietal bud placed on Nicolier-intershield
4. Completed Nicolieren bud-graft tightly bound

2A and 2B illustrate possibilities for combining Nicolier-intershield and varietal bud before inserting them in the stock.

Adapted from Krüssman by J. P. Mahlstede terial and information to us. I move that such a resolution be formed and adopted by this body before the close of the meetings.

The motion was seconded by Mr. Pieter G. Zorg, Fairview Nurseries, Fairview, Pa., and was carried by an unanimous voice vote.

CHAIRMAN FILLMORE: The first discussion on cuttings is by Mr. John Bos of Clyde, Ohio. I was very much interested in the outline of the paper which Mr. Bos showed me, because he places a real emphasis on the management of the stock block. He believes in stock blocks, he believes in managing them, and he evidently believes that if we would culture the plants as carefully for the production of cutting wood as we culture them for sale, a good many of our propagation troubles would be overcome at the outset. Mr. Bos will discuss the rooting of cuttings of golden philadelphus.

Mr. Bos presented his paper, entitled "Some Experiences in Rooting *Philadelphus coranarius aureus* Cuttings in Ohio." (Applause)

Some Experiences in Rooting Philadelphus coranarius aureus Cuttings in Ohio

JOHN BOS
John Bos Nursery, Clyde, Ohio.

We find that the stock plants are the most important factors. We have a few hundred stock plants, about 18-24" that never seem to get any larger because we keep taking cuttings off them every year. In the early spring during a few warm days, the buds on these plants tend to swell and develop into tiny leaves. Then a cold rain or light frost damages the edges of the leaves. These leaves will later grow out, but make poor cuttings. In fact we lose about one half of them; no matter how carefully the small brown ends are cut off when making the cutting, the loss is still 50%. Last summer we went to a local nursery that had some beautiful plants in the field with a lot of young growth that was free of blemishes or black spot. This man wanted us to root some cuttings for him. We took 700 cuttings, and have now 685 potted up and in the frame.

In order to obtain healthy cuttings, we have wondered if putting the stock plants under lath would help prevent damage to the foliage in the early spring. The very best way would be to plant about 50 stock plants and sit back for 6 or 8 years waiting for them to grow up to about 4 by 4 ft. Once these plants are up to size, trim out all the fine wood in the winter and each plant will produce about 300 healthy, sturdy cuttings. This older wood does not develop as early as do the buds on young plants, and is therefore not so apt to get leaf spot during a cold wet spring. It is our experience that before even making a cutting you are already 50% successful if you have a healthy cutting to start with.

We take the cuttings from the middle to the end of June. They should terial and information to us. I move that such a resolution be formed and adopted by this body before the close of the meetings.

The motion was seconded by Mr. Pieter G. Zorg, Fairview Nurseries, Fairview, Pa., and was carried by an unanimous voice vote.

CHAIRMAN FILLMORE: The first discussion on cuttings is by Mr. John Bos of Clyde, Ohio. I was very much interested in the outline of the paper which Mr. Bos showed me, because he places a real emphasis on the management of the stock block. He believes in stock blocks, he believes in managing them, and he evidently believes that if we would culture the plants as carefully for the production of cutting wood as we culture them for sale, a good many of our propagation troubles would be overcome at the outset. Mr. Bos will discuss the rooting of cuttings of golden philadelphus.

Mr. Bos presented his paper, entitled "Some Experiences in Rooting *Philadelphus coranarius aureus* Cuttings in Ohio." (Applause)

Some Experiences in Rooting Philadelphus coranarius aureus Cuttings in Ohio

John Bos
John Bos Nursery, Clyde, Ohio.

We find that the stock plants are the most important factors. We have a few hundred stock plants, about 18-24" that never seem to get any larger because we keep taking cuttings off them every year. In the early spring during a few warm days, the buds on these plants tend to swell and develop into tiny leaves. Then a cold rain or light frost damages the edges of the leaves. These leaves will later grow out, but make poor cuttings. In fact we lose about one half of them; no matter how carefully the small brown ends are cut off when making the cutting, the loss is still 50%. Last summer we went to a local nursery that had some beautiful plants in the field with a lot of young growth that was free of blemishes or black spot. This man wanted us to root some cuttings for him. We took 700 cuttings, and have now 685 potted up and in the frame.

In order to obtain healthy cuttings, we have wondered if putting the stock plants under lath would help prevent damage to the foliage in the early spring. The very best way would be to plant about 50 stock plants and sit back for 6 or 8 years waiting for them to grow up to about 4 by 4 ft. Once these plants are up to size, trim out all the fine wood in the winter and each plant will produce about 300 healthy, sturdy cuttings. This older wood does not develop as early as do the buds on young plants, and is therefore not so apt to get leaf spot during a cold wet spring. It is our experience that before even making a cutting you are already 50% successful if you have a healthy cutting to start with.

We take the cuttings from the middle to the end of June. They should be firm but not too hard. If there is no dew on them, we carry a pail of water and each handful of cuttings is immediately dipped in water. Once they wilt the tops turn crooked and will not straighten out. The cuttings are made about 6 inches long with mostly 4 leaves left on. The soft tips are removed. Position of the cut makes no difference, just below or in between a node. Personally, it is second nature with us to make the cut just below a node. This goes for all deciduous cuttings.

We have tried both vermiculate in a closed bench in the greenhouse and in sand under sash outdoors. We like sand the best. In sand the cuttings develop a finer root system and if they are handled carefully, they come out of the media with a small ball of sand attached. The sand we use is ordinary lake sand, not sterilized. Again if the cutting is healthy, hormones do not make any difference. We do not use any on the easier to root plants.

After the cuttings have been inserted in the frame, they are watered down thoroughly. The sash is then put on and they are shaded with lath shades. The laths should run north and south. They are shaded from about 8 till 5 o'clock. Syringing is done about 3 or 4 times a day. About the third day one can start looking for fungus or damping off trouble. We do not wait until the disease starts. At that time we begin spraying with a fermate solution in the morning instead of using the plain water for syringing. This is done every other day and after ten days every third or fourth day. About the third week the foliage seems to have hardened somewhat and the danger of damping off is greatly lessened.

About the first of August the cuttings are fairly well rooted and we start airing the sash, slowly at first and by the 15th they are ready to be potted. After potting they are put on a greenhouse bench and kept watered and syringed several times a day. The soil in the pots should be kept moist at all times. Also do not let drafts or excessive air circulation hit the newly potted plants. The ventilators are kept almost closed to increase the temperature and humidity. At about the third week young shoots start coming from the bottom of the pot and shortly thereafter they can be plunged in a cold frame for overwintering. During the winter months they are covered with sash and shaded. These plants will overwinter 100%.

Another way is to take the cuttings the latter part of August. They are made and inserted the same way as in June only we use No. 2 Rootone. In favorable weather they will be lightly rooted or heavily calloused in September before cold weather sets in. After the middle of November the shades are left on and we just forget about them, with the exception of an occasional watering along the edges of the frame.

In April the plants will start to grow but do not take them up too soon. In our eagerness to get as much work done as early as possible we potted them one year in early April. Apparently the roots were not strong enough to withstand the shock of moving and we lost over half of them. We now pot them the first of May when the first leaves are quite developed. They are placed on a bench in the greenhouse. They must be kept moist and free from drafts. By June 1, they are well developed plants with 6-8″ top growth.

At that stage our worries come to an end and then the other nurseryman must start thinking of how to get salable plants in the shortest possible time.

* * * *

CHAIRMAN FILLMORE: We thank Mr. Bos very much for his presentation. Time will permit only one question.

MR. FLEMER: Have you had any success with hardwood cuttings placed in the bench in winter?

MR. BOS: No, I have not.

* * * *

CHAIRMAN FILLMORE: Next is a discussion of a polyethylene case for rooting cuttings. This discussion will be presented by Mr. Roger G. Coggeshall of the Arnold Arboretum, whom I regard as one of the rising young men among propagators.

Mr. Coggeshall presented his paper, entitled: Propagation of Difficult Plants in a Plastic Case. (Applause)

Propagation of Difficult Plants in a Plastic Case

ROGER G. COGGESHALL
Arnold Arboretum, Cambridge, Mass.

The method of propagation that I am about to describe is both simple and inexpensive. The whole operation hinges upon the use of the plastic film called polyethylene. This is an air permeable, water impermeable plastic that allows for an exchange of oxygen and carbon dioxide, while at the same time retaining the moisture inside the plastic, thereby keeping the humidity very high.

This same plastic, as you may know, is now being used in a wide variety of ways, from packaging vegetables to balling plants.

Using this plastic that keeps the humidity so high, we built a frame out of one half inch strapping over a section of greenhouse bench. The frame was eight feet wide, eighteen feet long, and fifteen inches high from the surface of the medium.

Over this frame strips of polythene fifty-four inches wide and two thousandths of an inch thick were laid. By running the strips across the width of the case we were able to enclose it nicely with four sheets. An overlap of three inches was left on each sheet so that the case would be completely sealed.

Inside the case there were three different mediums: plain sharp sand; sand and Canadian peat mixed 50-50, and sand, peat and Styrofoam mixed by equal volume. The latter material, Styrofoam, an expanded plastic, was added to the medium to give better aeration.

kept moist and free from drafts. By June 1, they are well developed plants with 6-8″ top growth.

At that stage our worries come to an end and then the other nurseryman must start thinking of how to get salable plants in the shortest possible time.

* * * *

CHAIRMAN FILLMORE: We thank Mr. Bos very much for his presentation. Time will permit only one question.

MR. FLEMER: Have you had any success with hardwood cuttings placed in the bench in winter?

MR. BOS: No, I have not.

* * * *

CHAIRMAN FILLMORE: Next is a discussion of a polyethylene case for rooting cuttings. This discussion will be presented by Mr. Roger G. Coggeshall of the Arnold Arboretum, whom I regard as one of the rising young men among propagators.

Mr. Coggeshall presented his paper, entitled: Propagation of Difficult Plants in a Plastic Case. (Applause)

Propagation of Difficult Plants in a Plastic Case

ROGER G. COGGESHALL
Arnold Arboretum, Cambridge, Mass.

The method of propagation that I am about to describe is both simple and inexpensive. The whole operation hinges upon the use of the plastic film called polyethylene. This is an air permeable, water impermeable plastic that allows for an exchange of oxygen and carbon dioxide, while at the same time retaining the moisture inside the plastic, thereby keeping the humidity very high.

This same plastic, as you may know, is now being used in a wide variety of ways, from packaging vegetables to balling plants.

Using this plastic that keeps the humidity so high, we built a frame out of one half inch strapping over a section of greenhouse bench. The frame was eight feet wide, eighteen feet long, and fifteen inches high from the surface of the medium.

Over this frame strips of polythene fifty-four inches wide and two thousandths of an inch thick were laid. By running the strips across the width of the case we were able to enclose it nicely with four sheets. An overlap of three inches was left on each sheet so that the case would be completely sealed.

Inside the case there were three different mediums: plain sharp sand; sand and Canadian peat mixed 50-50, and sand, peat and Styrofoam mixed by equal volume. The latter material, Styrofoam, an expanded plastic, was added to the medium to give better aeration.

An electric heating cable, controlled by a thermostat, ran through the bottom of the medium. The thermostat was set to maintain a 76° temperature.

For an example of the procedure used in rooting cuttings I have chosen the results obtained with *Cotinus coggygria purpureus*.

Cuttings were taken the 18th of June and handled the following way: first the soft tips were removed. Then the cuttings were separated into four lots. The 10 cuttings making up Lot 1 were dipped into a talc powder containing 2% indole butyric acid (IBA). In Lot 2, ten cuttings were dipped into a 1% IBA-Powder. In Lot 3, ten cuttings were treated with Hormodin No. 3, and Lot 4 contained ten untreated cuttings.

The cuttings were then placed inside the plastic tent in the medium of sharp sand. They were watered in well with a hose, but the sand was not pounded around them.

Here they remained until they rooted with only the following care: the whole case was shaded with target cloth from about 10:00 A.M. until 5:00 P.M. on hot days. There were no daily syringings done inside the case and I can truthfully say it went untended inside for a week at a time. However, the medium starts to dry out after that time.

This is the main value of the plastic. Once the cuttings are well watered in and the medium good and moist, the case does not need to be attended to daily, except for shading. This does not mean that you should not take an occasional look at the cuttings, but as far as time consuming labor goes, it is greatly reduced.

The cuttings were lifted the 30th of June with the following results: 7 out of 10 had rooted with the 2% IBA, 3 out of 10 with 1%, 7 out of 10 with the Hormodin 3, and none were rooted in the control lot. The unrooted cuttings in the 1% lot and the control lot were restuck.

The rooted cuttings were potted into 2¼" standard pots, placed on the greenhouse bench, covered completely with a sheet of polythene film and shaded. They remained in this condition, with only the shade being removed, for about 10 days. At the end of this time the plastic was removed a little each day. By using this method to harden off the rooted cuttings we had a very good survival percentage, not just only with *Cotinus*, but with all other cuttings as well.

The two remaining lots of cuttings were lifted the 10th of July. By this time five more had rooted of the 1% lot to make a total of 8 out of 10, and in the control lot, where none were rooted on June 30th, 8 were now rooted.

Out of the four treatments the cuttings treated with 1% IBA and Hormodin 3 had the best root systems. The cuttings, treated with 2% IBA, were overdosed and had rooted too heavily, whereas, the cuttings in the control lot, even though they had rooted, rooted out on only one side of the cutting giving a one-sided root system.

These are the advantages of the plastic case. First, and foremost, it is a very economical unit to erect and maintain. Second, by having a plastic that maintains the humidity so high, cuttings can be taken a lot earlier than usual, contributing more than anything else, I think, to the encouraging results that have been obtained. And third, the amount of time required to operate such a unit is small.

Thank you, and if there are any questions I will do my best to answer them.

* * * *

MR. MARTIN VAN HOF: You said the cuttings were soft. Were they also thin?

MR. COGGESHALL: Yes, they were thin.

MR. VAN HOF: Why is it we have failed with soft, thin cuttings which were taken in August during the third flush of growth? They were treated with hormones, but all died.

MR. COGGESHALL: I think the reason is the difference in humidity. I have tried to root them in an open case and in a regular cutting case with a sash over them. In the polyethylene plastic case, the humidity is held so high that the cuttings don't get a chance to wilt.

* * * *

CHAIRMAN FILLMORE: We shall now have a discussion of the propagation of *Ilex cornuta Burfordi* as practiced by the Verhalen Nursery Company, Scottsville, Texas, and presented by Mr. John B. Roller. Mr. Roller is making his second appearance at our meeting. We certainly welcome him and we are glad to have members who will come so far to attend the meetings, especially when they have a contribution such as Mr. Roller will now present to us.

Mr. Roller presented his paper, entitled: Propagation of *Ilex cornuta Burfordi*. (Applause)

Propagation of Ilex cornuta Burfordi

John B. Roller
Verhalen Nursery Co., Scottsville, Texas

Our cuttings are taken from stock plantings that are to be grown for a period of five years, or from plants in containers. Our container plants, of course, are sold after one growing season so we use only cuttings from young vigorous stock. We have found that young plants give us faster rooting with higher percentage striking roots.

As to timing, our cuttings are taken after each period of growth has hardened without regard to calendar dates. The best time to take them varies from a few.days to weeks. We normally get two periods of growth on holly but in good seasons we can expect three. If we have an early spring our first cutting comes in June followed by cuttings in August and October. With a late spring we usually cut about July and September.

The type of cutting taken is as hard as can be had on early cuttings couraging results that have been obtained. And third, the amount of time required to operate such a unit is small.

Thank you, and if there are any questions I will do my best to answer them.

* * * *

MR. MARTIN VAN HOF: You said the cuttings were soft. Were they also thin?

MR. COGGESHALL: Yes, they were thin.

MR. VAN HOF: Why is it we have failed with soft, thin cuttings which were taken in August during the third flush of growth? They were treated with hormones, but all died.

MR. COGGESHALL: I think the reason is the difference in humidity. I have tried to root them in an open case and in a regular cutting case with a sash over them. In the polyethylene plastic case, the humidity is held so high that the cuttings don't get a chance to wilt.

* * * *

CHAIRMAN FILLMORE: We shall now have a discussion of the propagation of *Ilex cornuta Burfordi* as practiced by the Verhalen Nursery Company, Scottsville, Texas, and presented by Mr. John B. Roller. Mr. Roller is making his second appearance at our meeting. We certainly welcome him and we are glad to have members who will come so far to attend the meetings, especially when they have a contribution such as Mr. Roller will now present to us.

Mr. Roller presented his paper, entitled: Propagation of *Ilex cornuta Burfordi*. (Applause)

Propagation of Ilex cornuta Burfordi

JOHN B. ROLLER
Verhalen Nursery Co., Scottsville, Texas

Our cuttings are taken from stock plantings that are to be grown for a period of five years, or from plants in containers. Our container plants, of course, are sold after one growing season so we use only cuttings from young vigorous stock. We have found that young plants give us faster rooting with higher percentage striking roots.

As to timing, our cuttings are taken after each period of growth has hardened without regard to calendar dates. The best time to take them varies from a few days to weeks. We normally get two periods of growth on holly but in good seasons we can expect three. If we have an early spring our first cutting comes in June followed by cuttings in August and October. With a late spring we usually cut about July and September.

The type of cutting taken is as hard as can be had on early cuttings as we have been most successful taking them just as the terminal buds begin to swell just before they break into active growth. No particular attention is paid to position of cuttings on the mother plants. We like a sloping cut beginning just opposite a node. Length of cuttings should be four to five inches but they seem to root along the stem readily. We like to leave two or three whole leaves on the cutting, preferably three.

MEDIA: This may be surprising to some of you but the media we use is just sandy field soil. When the soil is first placed in the beds, peat moss is spaded in at the rate of one medium sized bale to approximately 160 square feet and then one bale after each crop is removed. Soil is never changed and some has been used for years without sterilization. However, we are fumigating with methyl bromide as we have apportunity, to kill weed seed. Fungus has been of no consequence. It has only been since we have been using plastic sheeting that is has appeared.

Our cuttings are treated with a solution of one gram indole butyric acid, three grams naphthalene acetic dissolved in two hundred cc isoproply alcohol. This is our base solution and we use 5 cc of this to one quart of water and with this we mix a thin mud solution of sticky red clay and as the cuttings are made they are dipped in this mud to a depth of 1½ to 2 inches. Mud should be right consistency to give a good coating and not run off or wash off easily. Our purpose in treating our cuttings by this method is this: it prevents drying out of the cuttings and makes it easier to store them for a few days if necessary.

CULTURE: Our propagating structure is a shade construction or lath house. Beds are built on the ground. We just rake a bed level, and firm it down, being sure that plenty of moisture is present and then cuttings are stuck in rows about three inches apart and one-half inch in the row. The dirt is packed down around them, they are thoroughly watered down, then a covering of plastic sheeting is laid over a wire framework made of No. 10 gauge concrete reinforcing wire cut in 5½ foot lengths, each end stuck inside the four foot bed, forming an arch. Dirt is shoveled on the edges of the plastic sheeting which is wide enough to lap about 8 inches on either side. This makes a bed that is practically air tight. Next, additional shade is suspended above the bed completing the job. If bed is properly watered and shaded in the beginning, no further watering is necessary for about three weeks. By this time the cuttings are rooted. Callus formation begins very quickly and is visible after four or five days. First roots can be expected in about sixteen to eighteen days with most rooted at 28 days at which time some of them will be coming into growth. No ventilation is given, except during watering, *if* watering is necessary.

Our practice is to remove shade and plastic sheeting and cover with sash covered with screen cloth, watering as needed. We usually pot them out of the cutting bed about eight weeks from the time they were made. The first spring cuttings are then heavy enough for fall planting in the field or planting directly into containers. We have cut our transplanting losses by application of liquid fertilizer daily for the first three to four days after potting. Even if they are in flush growth they can be safely potted by using Rapid-Gro, but shading is highly beneficial with tender plants.

* * * *

MR. HERBERT F. TRAUTMAN (Troutman Nurseries, Franksville, Wis.): Since Mr. Roller comes from Texas and I come from Wisconsin, I would like to call attention to the fact that the sun is much more effective in our locality than it is in Texas at the same time. You would probably have a more uniform daily amount of sunshine throughout the growing season than we would have. We have extremes of sunshine, which at the time the sun is the highest, would probably have quite an influence in rooting cuttings.

MR. ROLLER: I will say that temperatures inside these plastic tents may get as high as 110 degrees Fahrenheit. We have tried various types of plastic, including the opaque type. We find that we don't get much variation in rooting between opaque plastic and the clearer types. Light intensity definitely has to be cut down in our method of propagation.

MR. TRAUTMAN: What I was getting at is that you have a longer season of uniform temperature conditions for growth, whereas we have extremes in temperature. This was brought to my attention by a grower who claims that we get more growth in a shorter period of time than you do in the south. This is just something to consider.

MR. ROLLER: One thing I have noticed, too, even though we use the plastic and leave it out in the weather over winter, the cuttings root a little faster than by the old method of propagation. Rooting is definitely slower in the winter time than in the summer.

CHAIRMAN FILLMORE: I should like to comment about Mr. Trautman's statements concerning the amount of sunlight in the north as compared to the south. At the Equator, day and night are of equal length all year. As one moves northward, daylight is longer in the summer than it is at the Equator, and shorter in the winter. That is the answer to his question. There may be more heat units in Wisconsin in the months of July and August than there are in Texas, that is, it is possible, but there will certainly be longer day light in Wisconsin during July and August than in Texas.

The session recessed at 3:50 o'clock and reconvened at 9:30 p.m.

CHAIRMAN FILLMORE: We shall resume the program this evening with a discussion of the Phytotektor method of rooting cuttings. We are fortunate to have this method presented by its originator, Mr. H. M. Templeton of Winchester, Tennessee. Those of you who are members will have received a copy of the proceedings for last year and you will have noticed that Mr. Templeton is a junior member of the society. If Mr. Templeton can do this as a junior member, I wonder what he will be doing by the time he becomes a senior member.

MR. H. M. TEMPLETON: I want to apologize for reading this. There is so much I should like to say that I feel I must be efficient. I can't afford to ramble around.

Mr. Templeton discussed "The Phytotektor Method of Rooting Cuttings." (Applause)

The Phytotektor Method of Rooting Cuttings

H. M. TEMPLETON
Winchester, Tenn.

It is an honor to address this assembly of experts. It seems queer for me to stand here before you as a plant propagator because I am not. I am a machine operator. But I can tell you about a machine that apparently does know how to propagate plants. It is a device of wire and plastic and electrical equipment.

Since it has to have a name, we have called it the Phytotektor System. Each unit is 48 feet long and there can be as many units as you wish under one control system. It is an attempted union of the English sunframe idea and the new mist humidification.

The ideas came from Sheat's book, *Propagation of Trees, Shrubs, and Conifers,* from Mr Wells' excellent articles in the American Nurseryman on mist humidification, from advice of Professors Stoutemyer and O'Rourke, and from eight or ten thousand hours of thought and experiment on our part.

Its object is to root cuttings in soil, where they can grow-on without being lifted, potted, or transplanted, until such time as they are saleable or are strong enough to be mechanically transplanted into the field.

It is not a method of merely producing rooted cuttings. If it is your intention to lift the cuttings and pot them, you can beat this system with a greenhouse. You can beat it with a sash house and on some objects with the common cold frame. Again, if you intend to lift your rooted cuttings you can possibly beat it, under some conditions, with open air mist systems.

But, if you need large quantities of heavy, bare root liners with good secondary root systems, we don't believe you can equal it in either costs or results, except with some methods of open field production in the deep south.

Our procedure has been developed—and the control system is required —because we can't afford to throw continuous mist onto cuttings in soil. There simply isn't any place for the water to go, there isn't any drainage.

The controls used this year, humidistat and timer, were set up with the idea we wanted to keep the air within the enclosure saturated. The more we got into it, the less we thought of this concept, and the more convinced we became that what we really wanted to do was keep the leaves wet all of the time.

MR. H. M. TEMPLETON: I want to apologize for reading this. There is so much I should like to say that I feel I must be efficient. I can't afford to ramble around.

Mr. Templeton discussed "The Phytotektor Method of Rooting Cuttings." (Applause)

The Phytotektor Method of Rooting Cuttings

H. M. TEMPLETON
Winchester, Tenn.

It is an honor to address this assembly of experts. It seems queer for me to stand here before you as a plant propagator because I am not. I am a machine operator. But I can tell you about a machine that apparently does know how to propagate plants. It is a device of wire and plastic and electrical equipment.

Since it has to have a name, we have called it the Phytotektor System. Each unit is 48 feet long and there can be as many units as you wish under one control system. It is an attempted union of the English sunframe idea and the new mist humidification.

The ideas came from Sheat's book, *Propagation of Trees, Shrubs, and Conifers,* from Mr Wells' excellent articles in the American Nurseryman on mist humidification, from advice of Professors Stoutemyer and O'Rourke, and from eight or ten thousand hours of thought and experiment on our part.

Its object is to root cuttings in soil, where they can grow-on without being lifted, potted, or transplanted, until such time as they are saleable or are strong enough to be mechanically transplanted into the field.

It is not a method of merely producing rooted cuttings. If it is your intention to lift the cuttings and pot them, you can beat this system with a greenhouse. You can beat it with a sash house and on some objects with the common cold frame. Again, if you intend to lift your rooted cuttings you can possibly beat it, under some conditions, with open air mist systems.

But, if you need large quantities of heavy, bare root liners with good secondary root systems, we don't believe you can equal it in either costs or results, except with some methods of open field production in the deep south.

Our procedure has been developed—and the control system is required—because we can't afford to throw continuous mist onto cuttings in soil. There simply isn't any place for the water to go, there isn't any drainage.

The controls used this year, humidistat and timer, were set up with the idea we wanted to keep the air within the enclosure saturated. The more we got into it, the less we thought of this concept, and the more convinced we became that what we really wanted to do was keep the leaves wet all of the time.

With the old humidistat and timer control, at a power cost of $1.00 a month, the equipment, in effect, "examined" all of the cuttings once each five minutes, night and day, and supplied them with water each time they seemed to need it. That is 288 times a day, 8,640 times a month, for $1.00. You could literally put in a batch of cuttings and go off and forget about them.

However, if you accept the wet-leaf concept that is only approximate control.

We plan to use a little aluminum painted can for our new control. We think of it as the electronic leaf. It is not fully proven but we believe that it will "examine" our cuttings every instant of every day in 1954 and supply them with precisely the amount of water required to keep them wet.

You understand, as soon as a bed of cuttings is rooted we harden them up a little, remove the equipment and use it over again as many as three times a year, leaving the cuttings to grow in full sun, right out in the open, right where they rooted. There just aren't any handling costs.

Temperatures inside in the summer are very high, 115 degrees, in the winter very low. We can't really do anything about them, so we just don't pay any attention to them.

One thing is necessary, the cuttings must not be put in very deep, just deep enough to keep them from falling over—one inch, a half an inch, a quarter of an inch. That is what the thin layer of sand is for, it's an easily worked medium for holding the cutting upright. This shallow placement is a very real advantage with certain plants, barberry, for example, just stick it in one internode deep. You don't have to clip any thorns.

If the subjects require heavy hormone treatment, we place them about an inch deep in nail holes punched in the sand, and then simply flood them in. If no hormones are needed, we just jab the base of the cutting into the sand deep enough to hold it upright. This can be a very fast operation.

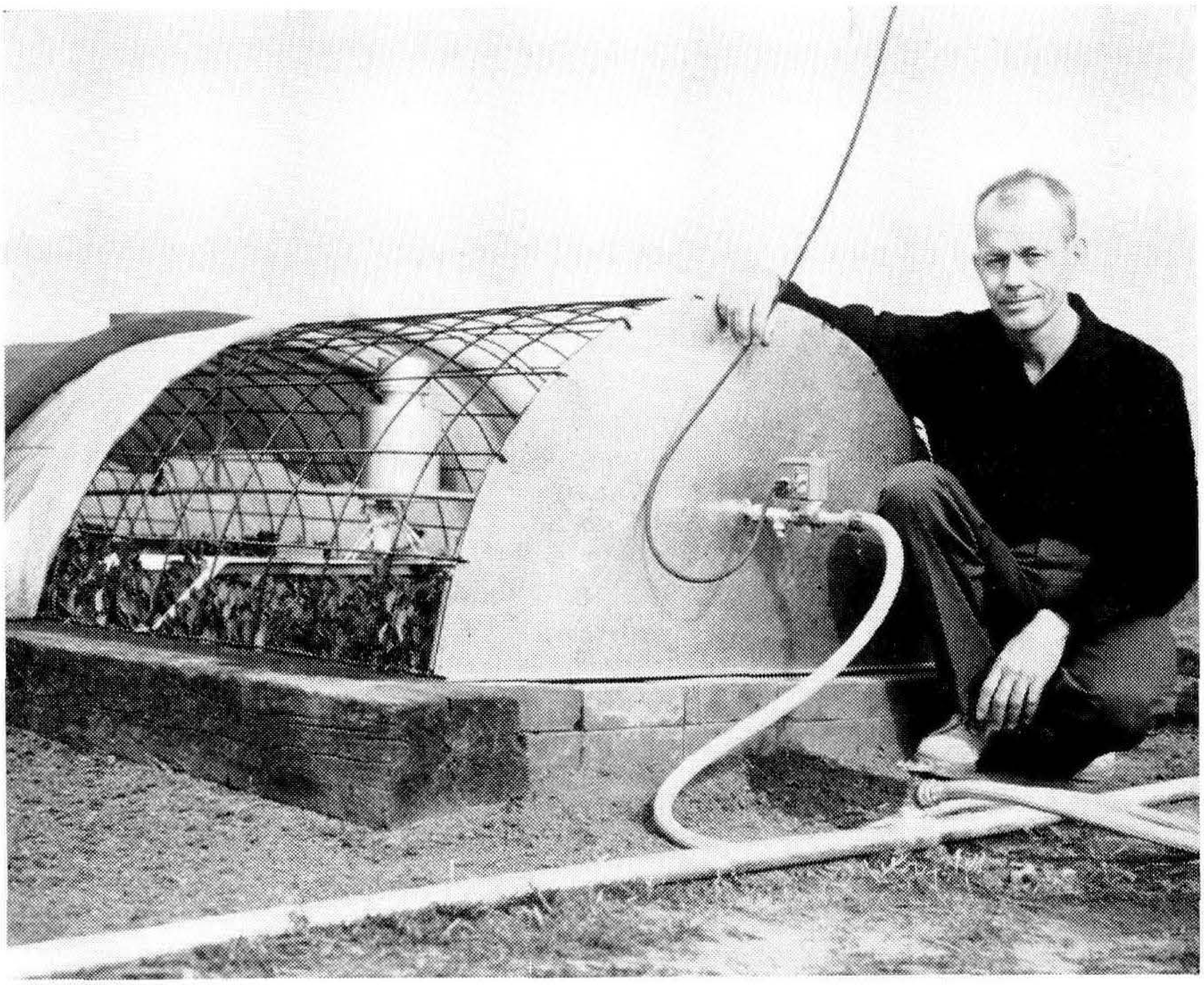
There are many interesting points that I do not have time to go into, but I would be very glad to discuss the method further with any of you who may be interested.

* * * *

MR. CASE HOOGENDOORN (*Hoogendoorn Nurseries, Newport, R.I.*): What is the reason you put those cuttings only in a quarter to a half inch?

MR. TEMPLETON: We put them in shallow because if we put them in deep they don't root. We have a clay soil which gets very wet. There is not much aeration.

MR. LESLIE HANCOCK: This is of very great interest to me because it uses soil as the rooting medium. We have developed a method at Cooksville, which will be described to you on Saturday afternoon, using soil as the rooting medium. I am curious to know how efficient it is to put



Mr. Templeton and The Phytotektor Apparatus.

the cuttings in and then to put all those gadgets over them. Is there a lot of equipment in the way to reduce efficient placement of the cuttings?

MR. TEMPLETON: No, cutting placement is very easy. First, we erect the entire apparatus, including the wire and spray line. We then take off one section of the wire at the end of the bed, set it aside, and put a temporary tent-house shelter over that section. The spray nozzle is turned on and the boys go into the tent house to stick the cuttings. As soon as that section is filled, the wire frame is put back in place and covered with plastic. We are then ready to start another section. The entire operation is very quick and easy.

PRESIDENT WELLS: Have you tested the possibility of providing drainage beneath the rooting medium so that the cuttings could be put in deeper?

MR. TEMPLETON: I don't think that it is necessary to put the cuttings in deep. It is easy to put them in shallow and they root satisfactorily. There seem to be two or three factors involved there.

PRESIDENT WELLS: What are the percentages of some of the things you have rooted in these frames?

MR. TEMPLETON: That we don't know. We don't count the cuttings when we put them in and don't count them when we take them out. We get what we think is an effective per cent. By that I don't mean that every cutting roots, obviously, they don't, but the first growing season we lost more cuttings because they choked themselves to death than we lost by not rooting.

MR. HOOGENDOORN: Do you firm those cuttings when you stick them?

MR. TEMPLETON: We stick them loose. It doesn't make any difference whether they are firmed or not. You won't believe this, and I didn't mean to tell this, but it is not even necessary to stick the cuttings at all. They will root on top of the soil.

MR. HOOGENDOORN: Do you use any shade after removing the plastic cover?

MR. TEMPLETON: Actually, you can just remove the cover. It hurts the cuttings a little, but you can get by with it. In practice, it is better to harden them off about a week. We do that by giving them air.

MR. HOOGENDOORN: Won't the cuttings get burned by taking the cover off all at once and exposing them to the sun? Wouldn't it be better to have shade over them for a week or so?

MR. TEMPLETON: With some plants I think so. Some broad-leaved plants show some sign of burning, but you can put them right out in the sun.

MR. CHARLES HESS (Hess Nursery, Mountain View, N.J): In New Orleans over 75 years ago, belljars were used. Propagators put a little sand on top of the dirt, put the cuttings in and covered with the belljar. The bell jar was tipped a little for ventilation. This is a somewhat similar procedure.

MR. SIDNEY WAXMAN (Cornell University, Ithaca, N.Y.): Roots will grow where there is oxygen and usually don't grow where there is no oxygen. If you have your cuttings stuck in sand, not dirt, you will have roots growing in the sand, but they will die if they are down where there is no oxygen. What makes you think they are going to grow into the dirt? You said before in dirt they will die and yet you take off the cover later on and leave them out in the sun.

MR. TEMPLETON: There is apparently enough oxygen there to encourage them to go on down into the dirt, because they do go on. There is no dying of roots. There is no sign of unhealthy roots. Roots start in the sand and on top of the dirt. By the time they are rooted, they are all down in the dirt.

MR. WAXMAN: Yet, you said that they won't root in the dirt.

MR. TEMPLETON: By that, I mean not as well. We can put cuttings in the dirt if it is very loose and if we don't use too much water. However these cuttings will not do as well as those in a sanded surface.

DR. SNYDER: You are suggesting that there might be a difference between the oxygen required for the development of the roots and for growth after the roots have formed.

CHAIRMAN FILLMORE: I think that it is very possible.

MR. MAURICE H. WILSEY (Wilsey Evergreen Nursery, Corfu, N.Y): In Professor O'Rourke's class at Michigan State, I have seen him put easily-rooted cuttings in wire baskets and just hang them on the well. The cuttings rooted in a very short time without any media at all.

MR. TEMPLETON: I have seen that done also. One of our men wanted to impress his father, so he tied a little bunch of cuttings and hung them inside one of the units. The cuttings rooted.

MR. MARTIN VAN HOF: How large are the cuttings you use?

MR. TEMPLETON: Apparently we can root cuttings just as big as we can get into the tent It is a compromise between a few large cuttings and a large number of small ones.

MR. VAN HOF: Then it makes no difference what size they are? Could they be eight or ten inches if they will stand up?

MR. TEMPLETON: Yes, place them thick enough so they will support themselves. You can't do this if you put a whole lot of little cuttings and a few big ones because the large ones do not get enough support from the small cuttings.

MR. DONALD S. McCONNELL (Port Burwell, Ontario): I was wondering if you had much experience with evergreen cuttings?

MR. TEMPLETON: Evergreen cuttings take a long time to root. It is a winter-time proposition with us. We put them in because we don't have anything else to put in at that time of the year. It takes evergreen cuttings the usual long time to root.

MR. McCONNELL: What is your experience with Japanese yew?

MR. TEMPLETON: We don't grow yews down there. I have made only limited experiments. They rooted well.

MR. HOOGENDOORN: You root mostly broad leaf evergreen plants?

MR. TEMPLETON: Mostly broad leaf.

PRESIDENT WELLS: I have the greatest respect and admiration for what Mr. Templeton has done and is doing, yet, I still think that in a few years he will have thrown his plastic away, because I believe that the future of propagation lies in the controlled use of water. I think water is the vital factor in his system and in a lot of other systems. I think he is on the right line in wetting the leaves and keeping them wet. His plastic simply is an artificial means of trapping heat which aids in propagation, but given the normal heat of a hot summer sun, I think it can be done just as well without any plastic. Incidentally, we rooted cuttings that accidentally had fallen off on the bench without being stuck and without any plastic. That is out in the open, simply by keeping them covered with water. Some cuttings would root far more readily if they had a greater light intensity, which could be provided by eliminating the plastic and shade.

MR. C. S. INGELS (Henry Nurseries, Henry, Ill.): Do you have any trouble with the nozzels plugging up and, if so, how do you get to the nozzles to clean them out without damaging the cuttings? How often do you check the apparatus?

MR. TEMPLETON: Yes, we have trouble with the nozzles clogging. I suppose we always will have trouble with low capacity nozzles. We have to clean about two per cent of them each day. We check them every morning. The boys simply walk down the lines of beds and look in a small square hole which is provided for inspection purposes. They turn the system on so all of the nozzles are spraying. If a nozzle is spraying, it is all right. If they find one that is not spraying, they mark the place and come back later. The nozzles are easily cleaned.

MR. HOOGENDOORN: There is a new apparatus, called the Evis Water Conditioner, which it is claimed will remove the minerals from the water. This should eliminate all nozzle trouble. It costs about $95.00.

CHAIRMAN FILLMORE: We are very grateful to Mr. Templeton for bringing the model of the Phytotektor to this meeting and for his excellent discussion of this method of rooting cuttings, however we must proceed to the next speaker.

The next discussion will be presented by Charles E. Hess, a graduate student at Cornell University, who will describe a simple timing device for controlling lights and nozzles.

Mr. Hess described a simple and inexpensive time clock for regulating mist in plant propagation procedures. (Applause)

A Simple and Inexpensive Time Clock for Regulating Mist in Plant Propagation Procedures

Charles E. Hess and William E. Snyder
Cornell University, Ithaca, New York

In the field of horticulture, time clocks are used to extend the length of day by turning lights on at dusk and turning them off again after the desired daylength is reached and for cyclic control of mist for plant propagation.

Three different timers were designed, built, used and then discarded in the development of the timer to be described. The first three timers failed to meet all the requirements of a practical instrument, namely, simplicity, economy, availability of parts and adaptability. This timer, therefore, is the result of testing three different designs, selecting the without any plastic. That is out in the open, simply by keeping them covered with water. Some cuttings would root far more readily if they had a greater light intensity, which could be provided by eliminating the plastic and shade.

MR. C. S. INGELS (Henry Nurseries, Henry, Ill.): Do you have any trouble with the nozzels plugging up and, if so, how do you get to the nozzles to clean them out without damaging the cuttings? How often do you check the apparatus?

MR. TEMPLETON: Yes, we have trouble with the nozzles clogging. I suppose we always will have trouble with low capacity nozzles. We have to clean about two per cent of them each day. We check them every morning. The boys simply walk down the lines of beds and look in a small square hole which is provided for inspection purposes. They turn the system on so all of the nozzles are spraying. If a nozzle is spraying, it is all right. If they find one that is not spraying, they mark the place and come back later. The nozzles are easily cleaned.

MR. HOOGENDOORN: There is a new apparatus, called the Evis Water Conditioner, which it is claimed will remove the minerals from the water. This should eliminate all nozzle trouble. It costs about $95.00.

CHAIRMAN FILLMORE: We are very grateful to Mr. Templeton for bringing the model of the Phytotektor to this meeting and for his excellent discussion of this method of rooting cuttings, however we must proceed to the next speaker.

The next discussion will be presented by Charles E. Hess, a graduate student at Cornell University, who will describe a simple timing device for controlling lights and nozzles.

Mr. Hess described a simple and inexpensive time clock for regulating mist in plant propagation procedures. (Applause)

A Simple and Inexpensive Time Clock for Regulating Mist in Plant Propagation Procedures

CHARLES E. HESS and WILLIAM E. SNYDER
Cornell University, Ithaca, New York

In the field of horticulture, time clocks are used to extend the length of day by turning lights on at dusk and turning them off again after the desired daylength is reached and for cyclic control of mist for plant propagation.

Three different timers were designed, built, used and then discarded in the development of the timer to be described. The first three timers failed to meet all the requirements of a practical instrument, namely, simplicity, economy, availability of parts and adaptability. This timer, therefore, is the result of testing three different designs, selecting the desirable components of each and combining them into an economical and efficient instrument.

The final design includes some of the features of the earlier models and is very adaptable. The timer is actually two timers in one. One part controls the overall operation, that is it turns the timer on for any duration, such as on at eight in the morning and off at four in the afternoon. The second part controls the on and off periods of mist in such a way that repeated cycles of any duration can be obtained, for example—cycles consisting of two minutes of mist and four minutes without mist. The two timers can be used separately or together as it is here. Also since this timer controls the flow of electricity, it can be adapted to control any system which requires regularly repeating flows of current over any given period of time. When used to control the flow of water, a magnetic valve, called a solinoid valve, is a necessary component in order to shut off the water supply to the spray nozzles.

Simplicity can best be shown by describing the five steps in the building of the timer. Basically the timer consists of a motor with concentric shafts, one makes one revolution per day, the other one revolution per hour. Disks are attached to these shafts, and on the disks are projections which activate microswitches.

The first step is to cut two disks from 1/16 inch plastic, aluminum, or similar material, one having a diameter of 8¼ inches, the other six inches. The larger disk, which is attached to the one revolution per hour shaft, is divided into 120 sections. Therefore each section is equivalent to 30 seconds. A hole is drilled in the middle of each section ⅜ inch from the edge. (Drill size approximately 3/32 inch.) The small disk, to be attached to the one revolution per day shaft, is divided into 24 sections, each section representing an hour. A hole is also drilled in the middle of each 24 hour section ⅜ inch from the edge. (See Fig. 1)

The second step is to make the pieces which when attached to the disk will activate the microswitch. The projections for the one rph disk was made the same size as the divisions on the disk. The authors made a pattern on the same type of material from which the disk was cut. Before cutting the pieces apart, two holes were drilled in each piece—the first hole in the same position as that on the disk, i.e. in the middle, ⅜ inch from the edge, and the second hole immediately behind the first. The small amount of material remaining between the two holes is then drilled out thereby leaving a slot. The pieces are then cut apart. The same procedure is followed for making the projections for the one revolution per day disk. The hour sections were used for a pattern.

The number of projections required depends upon the type of cycle desired. For example if it is desired to have 30 seconds of mist every 20 minutes, operating eight hours a day, these "thirty-second" projections are needed on the one rph disk and eight "hour" projections are required on the revolution per day disk. Also by placing two "thirty-second" projections together, one minute of continuous mist can be obtained; three projections equal a minute and a half, etc. It is possible, therefore, by using various combination of "thirty-second" projects to vary the mist period from 30 seconds on and 59½ minutes off to an hour of continuous mist. Similarly, the overall operation can range from one hour on and 23 hours off to 24 hours on.

The projections are attached by using small machine screws. When it is desired to decrease the length of the "on" cycle, the screws are loosened and the projections are pushed back so they are flush with the edge of the disk or they may be removed entirely. Correspondingly, to increase the "on" cycles, the projections need only to be added or to be pushed out to extend beyond the edge of the disk.

The third step is to attach the disks to the timer. The revolution per day disk is attached first. A flange with an interior diameter equal to that of the shaft is attached to the disk with the same size machine screws as used for attaching the projections. A small pulley may be used if a flange is not available, however, it is necessary to remove the upper half of the pulley in order to leave room for the other disk. Holes are drilled in the lower half of the pulley and the disk, and the parts are held together with machine screws. The flange or pulley is also held together with machine screws. The flange or pulley is held to the shaft by set screws provided in the collar. The revolution per hour shaft has flattened sides and is threaded, therefore no flange is required. A hole is cut in the disk to correspond exactly with the shaft. The disk is fitted on and held in place with a nut.

The fourth step is to construct a container for the timer and provide for the attachment of the microswitches. The authors suspended the timer between two wooden bars. The bars were attached to the sides of the timer box. Next a bottom is fitted and screwed in place so that it may be removed if it becomes necessary. The microswitch for the revolution per disk is fitted onto the bottom of the timer box. Wooden blocks were used to bring the level of the microswitch lever even with the disk. The distance from the disk to the switch is adjusted so that an extended projection will turn the switch on Since the timer motor does not have enough force to throw heavy switches it is of utmost importance that the switches are of a type which require the least amount of force to activate them. The authors found a single pole, single throw microswitch very successful. It is supplied by the same company which supplied the timer motor. The microswitch for the revolution per day disk is located on the wooden bars which support the timer. It may be necessary to solder a thin piece of metal to the arm of the switch so that it will be wide enough to make contact with the disk. A wooden block cannot be used here because the side of the microswitch would interfere with the disk and its projections. (See fig. 2)

Wiring is the final step. The diagrams are shown in Figure 3. Four terminals are required: two for the incoming power and two for the power going to the solinoid. Wires from the timer are attached to the incoming power terminals. Next a wire from the outside power terminal is attached to the microswitch activated by the revolution per day disk. A wire from the "normally on" side of this microswitch is connected to

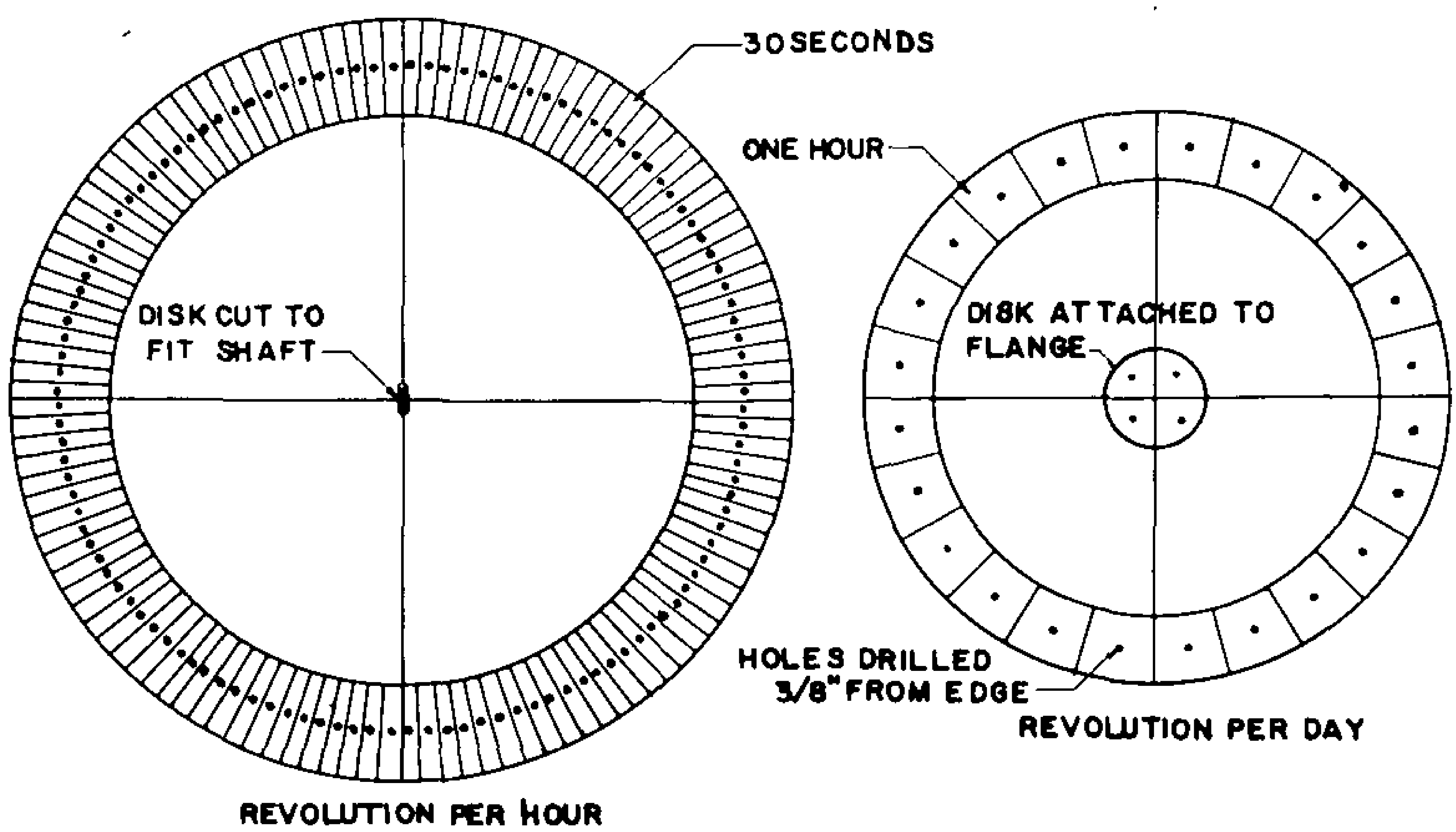


FIG 1 REVOLUTION PER HOUR AND DAY DISKS

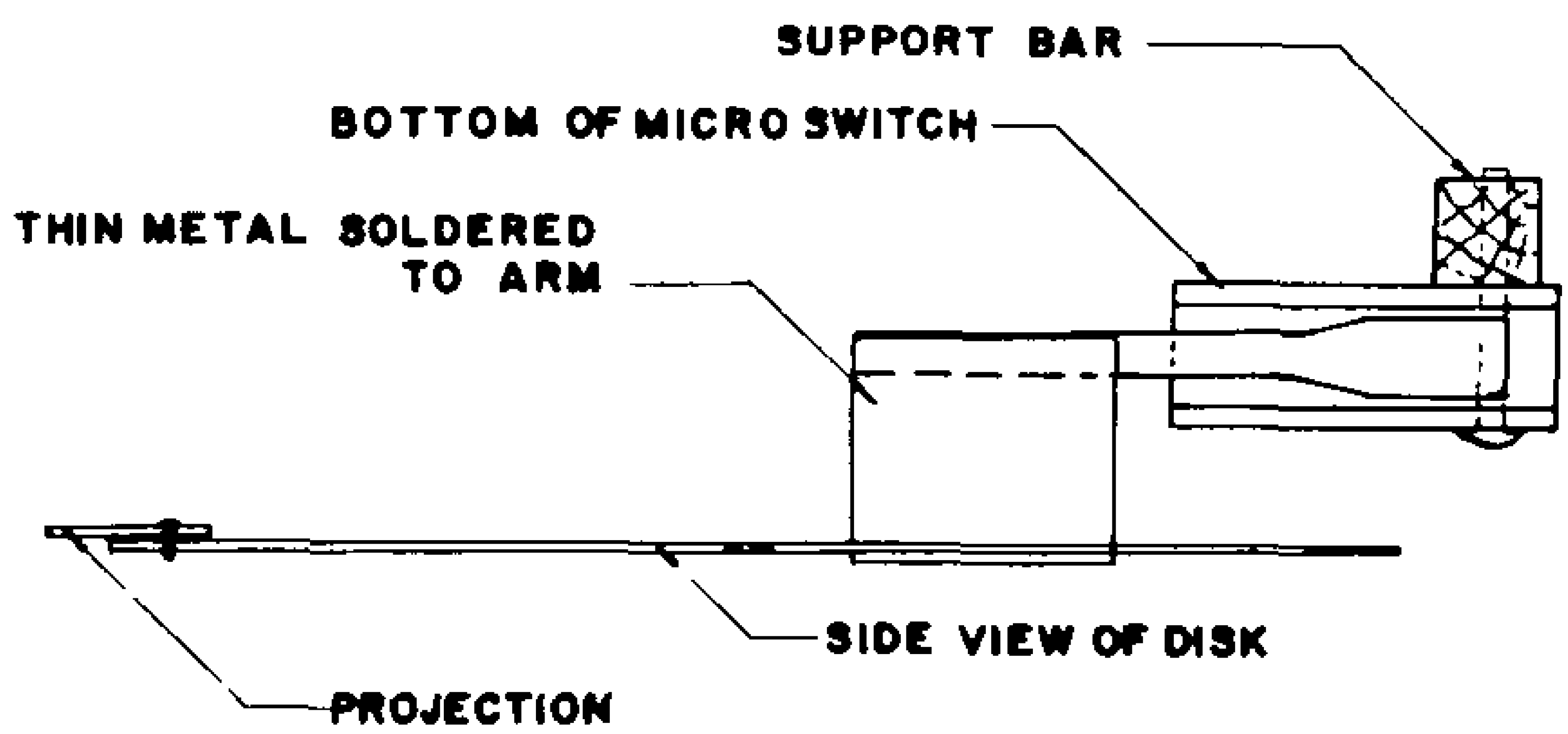


FIG 2 ATTACHING REV PER DAY MICRO SWITCH

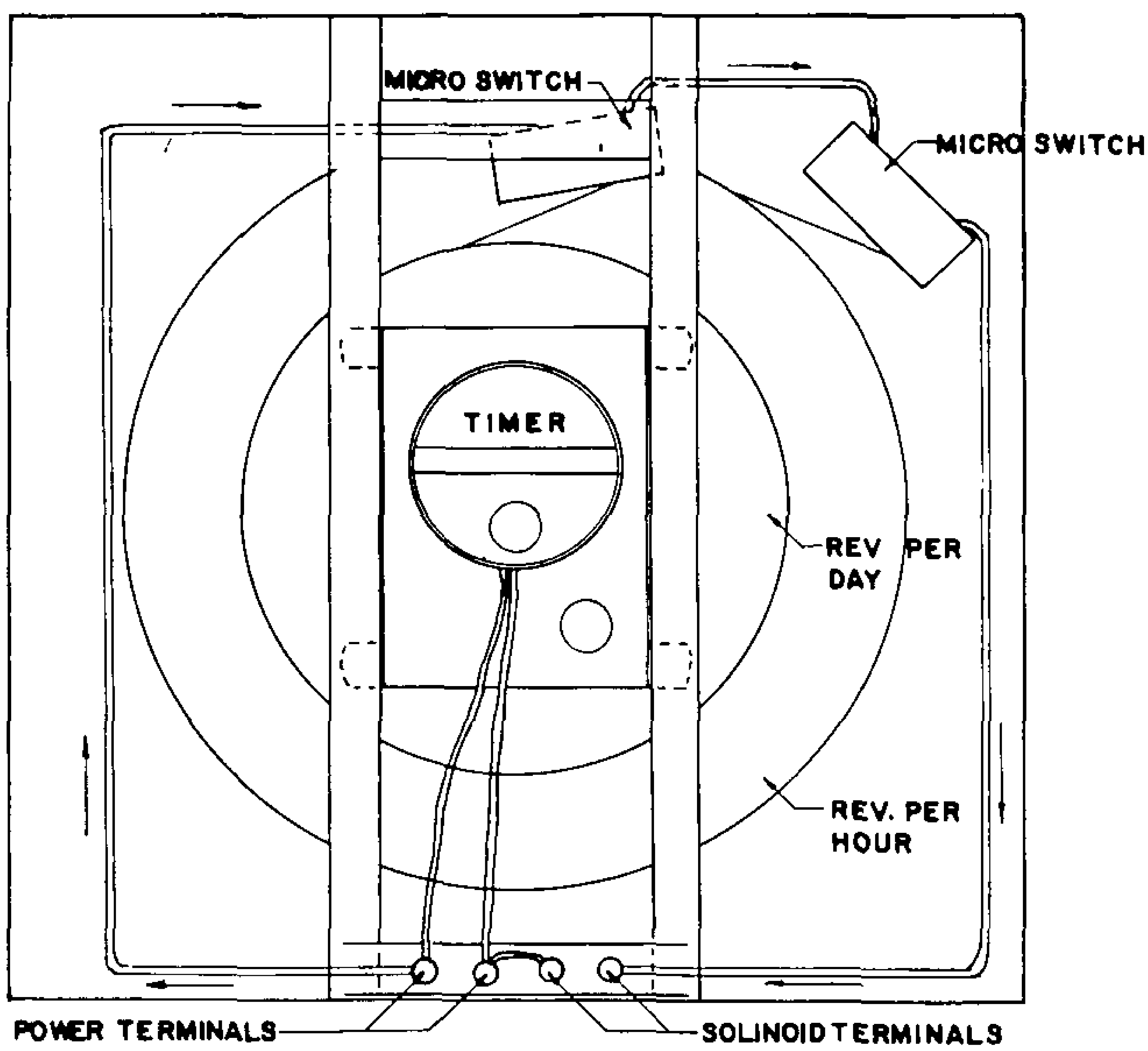


FIG 3 ARRANGEMENT OF MICRO SWITCHES AND WIRING

the microswitch activated by the revolution per hour disk. A wire from "normally open" side of this switch is attached to one of the terminals which go to the solinoid. Finally, a wire from the inner incoming terminal is attached to the second outgoing or solinoid terminal. Thus the first switch controls the overall operation and the second the cycles of mist.

This completes the timer other than attaching the solinoid wires, setting the time by means of a shaft and a knurled nut provided with the motor, and plugging in the power line.

Economy and availability of parts are the last two factors to be considered. Economy is shown by table 1 which lists the cost of the basic parts and gives an approximation of the cost of labor.

The timer motor and microswitches, although probably obtainable from any electronics supply firm, were purchased by the authors from Herbach and Rademan, 1024 Arch Street, Philadelphia 7, Pennsylvania.

TABLE 1. COST OF MATERIALS

Timer motor		$ 6.75
2 microswitches .40 ea.		.80
Material for disks and container		3.00
Total		10.55
Labor: 5 to 9 hours	5.00 to	10.00
Entire cost approximately	$15.00 to	20.00

CHAIRMAN FILLMORE: This is an ingenious timing device which has been described by Mr. Hess. Thank you very much for the information.

MR. TEMPLETON: Do you use this in connection with any other device, such as a humidistat which would cut off the timer during rain?

MR. HESS: The timer has been used for cuttings and preliminary work for grafting. We did have humidistats placed in the area considered to be most critical, that is, in the area where the cuttings were. When the mist is on moisture filters into the humidistat and it takes a considerable period for this to dry off. The plants will dry off before the humidistat becomes effective in starting the mist. It is possible that by proper placement, a humidistat could be effective.

DR. SNYDER: A question was asked of Mr. Templeton concerning the cleaning of the nozzles. Will you describe the mechanism of the nozzles used by us this summer?

MR. HESS: There are several things which can be said about these nozzles. The main thing is that by reducing the time the mist is on, we used less water, thereby both prolonging the life of the nozzle and reducing the possibility of clogging. During the preliminary work this past summer, we used cycles consisting of two minutes on and four off. Under conditions of continuous mist, 63 gallons of water were used during a twelve hour period, but with the cyclic system, only 21 gallons of water were used.

We used a nozzle which has a cleaning device in it. When the nozzle shuts off, the nose is drawn into the body by a spring and there is a prong or needle which penetrates the aperture of the nozzle. These nozzles were very good and we haven't had any trouble with clogging so far. However, they are expensive nozzles, retailing for $8.00 each.

PRESIDENT WELLS: What mediums were used?

MR. HESS: The medium we used was peat and sand in proportion of one-third peat to two-thirds sand. I think that actually the medium is not too important with regards to mist. It might be thought that the medium will become waterlogged and deficient in air. There are two factors involved here: first, as the mist goes through the air, it picks up quite a bit of oxygen. Secondly, when the mist is off, the water is draining from the cuttings, penetrating the medium, and draining from the bench. In the experiments which we ran, we found less basal rot on those cuttings under the mist than those which were propagated in a closed case and in an open bench.

It may also be that there are a certain number of fungus spores washed off the leaves by the mist. That is where this idea of getting a film of water, water which actually drips off the leaves, comes into play. Among the beneficial effects from the mist may be removal of fungus spores, increased aeration of the medium, and cooling of the tissue.

* * * *

CHAIRMAN FILLMORE: Since Mr. Spencer B. Chase is not present this evening, we will proceed to the last of the speaker-exhibitors. Roger W. Pease, of West Virginia University, is a holly enthusiast and one of the early supporters of the Plant Propagators Society. I am certain that he will present a very interesting discussion on the use of overhead irrigation of holly.

Mr. Roger W. Pease presented his paper, entitled: "The Response of Rooted Cuttings of *Ilex opaca* to Overhead Irrigation in a Lath House." (Applause)

The Response of Rooted Cuttings of Ilex opaca to Overhead Irrigation in a Lath House[1]

ROGER W. PEASE
University of West Virginia, Morgantown, W. Va.

During the wet season of 1951 rooted cuttings of *Ilex opaca*, transplanted in April from the rooting cold frame to a clay soil, averaged 5.4

[1]Published with the approval of the Director, West Virginia Agricultural Experiment Station, as Scientific Paper No 479.

twelve hour period, but with the cyclic system, only 21 gallons of water were used.

We used a nozzle which has a cleaning device in it. When the nozzle shuts off, the nose is drawn into the body by a spring and there is a prong or needle which penetrates the aperture of the nozzle. These nozzles were very good and we haven't had any trouble with clogging so far. However, they are expensive nozzles, retailing for $8.00 each.

PRESIDENT WELLS: What mediums were used?

MR. HESS: The medium we used was peat and sand in proportion of one-third peat to two-thirds sand. I think that actually the medium is not too important with regards to mist. It might be thought that the medium will become waterlogged and deficient in air. There are two factors involved here: first, as the mist goes through the air, it picks up quite a bit of oxygen. Secondly, when the mist is off, the water is draining from the cuttings, penetrating the medium, and draining from the bench. In the experiments which we ran, we found less basal rot on those cuttings under the mist than those which were propagated in a closed case and in an open bench.

It may also be that there are a certain number of fungus spores washed off the leaves by the mist. That is where this idea of getting a film of water, water which actually drips off the leaves, comes into play. Among the beneficial effects from the mist may be removal of fungus spores, increased aeration of the medium, and cooling of the tissue.

* * * *

CHAIRMAN FILLMORE: Since Mr. Spencer B. Chase is not present this evening, we will proceed to the last of the speaker-exhibitors. Roger W. Pease, of West Virginia University, is a holly enthusiast and one of the early supporters of the Plant Propagators Society. I am certain that he will present a very interesting discussion on the use of overhead irrigation of holly.

Mr. Roger W. Pease presented his paper, entitled: "The Response of Rooted Cuttings of *Ilex opaca* to Overhead Irrigation in a Lath House." (Applause)

The Response of Rooted Cuttings of Ilex opaca to Overhead Irrigation in a Lath House[1]

ROGER W. PEASE
University of West Virginia, Morgantown, W. Va.

During the wet season of 1951 rooted cuttings of *Ilex opaca*, transplanted in April from the rooting cold frame to a clay soil, averaged 5.4

[1]Published with the approval of the Director, West Virginia Agricultural Experiment Station, as Scientific Paper No 479.

inches of growth when shaded and protected by six inch porous drain tile one foot high. The plants were mulched with sawdust and fertilized with both cottonseed meal and a 5-10-10 mixture. During the comparatively dry season of 1952 cuttings from the same clones, given similar treatment, showed negligible growth. No water supplementary to rainfall was applied during either season Because of these observations it was thought that water in excess of rainfall might be advantageous to the growth of rooted *Ilex opaca* cuttings, especially during a dry season. It also seemed possible that rooted cuttings carried for the first growing season in a lath house with well-drained soil and overhead irrigation would show unusually good growth.

In the fall of 1952 a lath house was constructed which admitted one half constant light and had tile drainage, a crushed rock and sand fill to cover the tile, and a soil medium of one third light soil, one third sand, and one third rotting leaves and forest litter A line of half inch pipe was run about ten inches over the soil medium. Skinner Superior nozzles were mounted on the pipe, and water was supplied by the city system. Ammonium sulphate was spread over the soil bed late in the fall, at the rate of one pound to about forty square feet.

In April, 1953, sixteen rooted cuttings of *Ilex opaca* were selected at random from each of two clones characterized by vigorous, upright growth. Eight rooted cuttings from each clone were transplanted into the lath house at about six inch spacing. Approximately one half tablespoonful of 5-10-10 fertilizer was applied per square foot. No other fertilizer was added during the growing season. Whenever the surface of the soil was dry, the irrigation system was turned on late in the afternoon and left on until water ran from the drain.

On the day when the holly was set in the lath house, the remaining eight rooted cuttings from each clone were transplanted. They were set in two rows in a clay soil to which sawdust and fertilizer had been added annually for several years The spacing was six inches in the row and two feet between rows. 5-10-10 fertilizer was added at the same rate as in the lath house. Six-inch porous tile were placed over the plants, and about four inches of peat moss was spread to cover the entire plot. Cottonseed meal was spread over the peat moss, allowing about one half cup to a plant. Neither water nor additional fertilizer was added during the season.

On September 20 height measurements of the holly were taken. Clone I, grown without irrigation, showed a survival of six of eight plants and an average height of 4.18 inches among the survivors The median height was 4.5 inches. The same clone, grown under irrigation, showed 100% survival and an average height of 13 83 inches The median height was 13.5 inches. One non-irrigated plant of clone II died, and the other seven averaged 4 29 inches in height, with a median height of 5 inches. Under irrigation clone II showed no mortality, an average height of 13.5 inches, and a median height of 14.5 inches.

These results should not be interpreted to show that the growth differences obtained were caused by irrigation only. Irrigation, soil characteristics, drainage, methods of shading, may all have been contributing factors. Since the city water used in the trials had been observed to damage the foliage of cuttings under continuous mist, it is possible that growth differences might have been greater if more suitable water had been used.

* * * *

CHAIRMAN FILLMORE: Thank you very much, Roger, for an informative discussion on the American holly.

MR HARVEY GRAY: Did you note whether you had more than two spurts of growth? In other words, was there an interruption in growth during the season?

MR. PEASE: Yes, I definitely did notice interruption in the growth of holly, however the spurts were more noticeable in rhododendron. In the holly, you can't trace these spurts after the season's growth. My memory would say there were two spurts and the second grew much farther than the first.

MR. GRAY: In holly, for a salable plant, we like to have one that is well branched. Have you made any check to determine whether a pinching at the close of the first spurt of growth might encourage lateral branching rather than a continuous straight growth?

MR. PEASE: Again, I did not try that with holly. I wanted to see how high I could get the plants in one season. Accidentally, I tried it with some rhododendrons The central leader was broken off and on the second spurt of growth two or three lateral shoots developed. That was on just one plant however.

MR. GRAY: On rhododendron, concerning the breaking of the strong terminal growth, it is very true that more than one break develops. I have noticed in this general connection that major breaking possibly develops on the first spurt of growth each season. The secondary and tertiary growth, that might be developed from laterals rather than the terminals, are not as numerous as they are on the first spurt of growth.

MR. TEMPLETON: There seems to be hardly any limit to the amount of fertilizer holly can use. In stands of holly so thick the plants were actually choking themselves, we put 4,000 pounds of 6-12-12 fertilizer to the acre in four applications. Applications were two or three weeks apart and at a rate of 1000 pounds to the acre. Every time we put it on, we could see a response to it. It responded to the four applications. It might have responded to a fifth, too.

American holly seems to take enormous quantities of water if it is in a heavy stand. They were growing in beds and we had to furnish them lots of water. We noticed that of all the plants we were growing, American holly wilted quickest.

MR. DON VANDERBROOK (C. W. Stuart Nursery Co., Newark, N.Y.): Does the fact that your municipal water is heavily chlorinated have any effect on the plants used with a mist system?

MR. PEASE: I couldn't answer that. Our water is heavily chlorinated. It also contains many other minerals. I noticed that the leaves became coated with white substance which I couldn't wash off. It was very harmful. I took some leaves to the biochemists and they couldn't get the material off to analyze it.

MR. HOOGENDOORN: Mr. Templeton says that he keeps feeding fertilizer continuously every two or three weeks and he has good response. By that excessive feeding, don't you weaken the plants and make them softer? Will they stand the winter?

MR. TEMPLETON: Apparently. Every time we put on an application of fertilizer the plants make further growth and they held up perfectly over winter.

MR. PEASE: In our West Virginia climate, where we get sudden cold weather, I have found that using cottonseed meal or any slowly-available nitrogen fertilizer, may cause a great deal of winter damage.

American Holly Clone 1 has rust spots all over it, and that is definitely due to letting it go into winter too soft. I've checked it year after year. Therefore, for practical purposes, I wouldn't advise anybody to push holly the way I did in this experiment.

PRESIDENT WELLS: Many of you may not have heard of Dr. C. W. Thornthwaite. He is an international expert on climatology. He has devised a method of measuring water loss which sounds complicated, but really isn't. He pointed out to me that a tin can is an ideal piece of equipment for determining water loss. Many of us are interested in growing nursery stock in containers and a container is an excellent evapo-transpirometer, which is what he calls his equipment for measuring water loss.

Water loss can be in either of two ways. It is evaporated from the soil surface or transpired from the plant and so the combined loss is evapo-transpiration. Water loss can be determined by weighing a can of soil containing a plant and determining how much the weight decreases. The decrease is the water lost by evapo-transpiration. You can also determine how much water the soil should have at full field capacity.

It has been proven that if you can maintain the soil as close as possible to full field capacity, about 90%, you will obtain optimum growth and you will not require any other protection against sunlight. In fact, you can use the maximum sunlight for growth The controlling factor is water. I think that Dr. Thornthwaite could give us some valuable and fundamental information. Perhaps we might have him here next year.

CHAIRMAN FILLMORE: That concludes the formal portion of the speaker-exhibitor session. It has been an interesting and informative session. At this time I want to call your attention to the exhibits in the room. We appreciate each exhibitor's contribution and hope that each of you will find the time to look at them.

a given author, I take full responsibility. I realize that several of the people who have published on junipers are here and that they may disagree with my interpretation of their work.

Many of the papers are quite old and the points of view held by some of these investigators at the time they wrote the papers may not necessarily be the point of view which they currently hold.

Dr. Snyder presented his paper, entitled "The Fundamentals of Juniper Propagation." (Applause)

The Fundamentals of Juniper Propagation

WILLIAM E. SNYDER
Cornell University, Ithaca, New York

Junipers can be propagated by seeds, layering, cuttings, and grafts, however layering is not a common commercial practice. Propagation by seeds is mainly for the production of understock or for seedlings for reforestation. Cuttings and grafts are employed in the production of the many species and varieties used in ornamental plantings.

PROPAGATION OF LAYERING. Sheat (50) has described the procedures to follow in the layering of various types of junipers, and Bannon (5) has studied the origin of roots in naturally layered plants of *Juniperus communis depressa, J. horizontalis,* and *J virginiana.* He found that the adventitious roots arose in the vicinity of the vascular rays—an origin comparable to the origin of roots of *Taxus cuspidata* and many other woody plants.

PROPOGATION BY SEEDS. The red cedar, *Juniperus virginiana,* is used as understock for grafting the numerous varieties used in ornamental plantings and also for reforestation in many areas of the United States. Since cuttings of this plant are difficult to root, the only practical method of propagation is by seeds. As is true for many of the woody plants of the temperate area of the world, the seeds are dormant and require special treatment before germination will take place.

Many investigators have emphasized the desirability of collecting the seed as soon as the berries become ripe (2, 26, 46, 51, 52, 61) Wyman (61) has suggested October 15th as an average date in the vicinity of Boston, while early November is reported to be the time of ripening of juniper berries in the vicinity of Stillwater, Oklahoma (2).

The quality of the seed of red cedar, as determined by cutting open the seed and by germination tests, indicates considerable variability from one locality to another, from year to year, and from tree to tree. Twenty percent good seed is not uncommon and very good lots of seed may contain only fifty percent viable seed (2, 44). Gerbracht (29) obtained only 500 seedlings of red cedar from two quarts of berries. He estimated that represented only about five percent of the total number of seeds planted. In contrast, Pack (44) has reported that the seed of the common juniper

(*Juniperus communis*) and of the creeping juniper (*J. horizontalis*) are of considerably better quality.

The fruit of juniper is a sort of berry which is bluish-black in color and contains from one to three seeds. Steavenson (51) has reported that by using a hammer mill to clean the seeds, 160 pounds of red cedar were obtained from 623 pounds of berries, while 892 pounds of seed of the Ozark white cedar (*J. Asheii*) were obtained from 7000 pounds of berries.

Seeds of juniper vary considerably in size and weight. There are only about 300 seeds per ounce of *J. californica,* approximately 2000 seeds per ounce of *J. horizontalis,* and 3000 seeds per ounce of *J. communis depressa, J. communis saxatilis, J. sabina,* and *J. virginiana* (30, 49, 57).

The presence of the fruit coat inhibits the after-ripening of the seed. Afanasiev and Cress (2) obtained only ten percent germination and Parker (46) reported no germination following stratification of intact berries. Evenari (28) has reported that Ullman found a germination inhibitor in the fruit of *J. communis.* Since the fruit of many species of plants have been found to contain germination inhibitors, it is quite possible that the fruit of other species of juniper may also possess chemical materials that retard or prevent germination.

Webster and Ratliffe (63) and Steavenson (51) recommend the use of a hammer mill to clean the seed. Jelley (32) wrung the berries through a wringer before washing the seed clean. Afanasiev and Cress (2) recommended the traditional soaking-fermentation procedure for cleaning the seed.

All investigators are in agreement that the seed of the red cedar, and of the relatively few other junipers which have been studied, possess a dormant embryo and that a period of stratification is necessary to overcome this dormancy. Whether or not the seed coat may also contribute to the dormant condition of the seed is not clear from the literature.

In 1921, Pack (44) reported that the seed coat of red cedar prevented the expansion of the non-after-ripened embryo. Chadwick (13, 14) has reported that one of the causes of dormancy is a waxy layer on the outer surface of the seed coat. He recommended soaking the seed for several hours in alcohol or a hot water treatment prior to stratification. Miss Barton (6), on the other hand, reported that the impermeability of the seed coat to water in a large percentage of the seed retarded after-ripening and recommended a 30 minute soaking in sulfuric acid or a moist storage for 4 to 8 weeks at 77° F. prior to stratification.

Gerbracht (29), Webster and Ratcliffe (63), and Steavenson (51) have recommended the soaking of seed in a weak lye solution prior to stratification. Afanasiev and Cress (2), however, have reported no beneficial effects from the lye treatment.

Parker (46) found that scarification prior to the stratification treatment resulted in an increase in the rate of germination but no affect on the final percent of germination of the seeds of red cedar. Miss Barton (6) has reported an increase from 34 to 63-77 percent in germination if the seeds are treated to render the seed coats permeable prior to stratification. Afanasiev and Cress (2) reported that the seeds increased 18.25% in weight during a 72-hour soaking in water and that removal of the seed coat did not facilitate germination. It was their conclusion that the seed coat was not involved in the dormancy.

After-ripening, which is the term used to designate the changes which occur in the seed during the period of stratification, apparently can occur at temperatures of 32 to 50° F. With most lots of seed, a temperature of 40° F. is optimum (6, 13, 14). Although most seeds require three months of stratification, some seeds may require as little as 70 days, while others as much as 120 days to complete the process of after-ripening (2). Germination of the seed may occur at the temperature of stratification, although Chadwick (13, 14) and Afanasiev and Cress (2) have reported a temperature of 50 to 55° F. to be optimum. Temperatures in excess of 65° F. retard germination. It has been found (2) that if after-ripened seed are permitted to dry out before germination they again become dormant, a condition known as secondary dormancy. This secondary dormancy is not as strong as the initial dormancy and fewer months of stratification are required to overcome it.

Investigators have studied the changes which occur within the seeds of *J. virginiana* (45) and of *J. scopulorum* (1) during the after-ripening process. In general these changes are:

a) an increase in enzymatic activity
b) a change in the form of the food material
c) a dispersal of reserve food materials within the seed
d) an accumulation of cell building materials.

It is more than likely that these changes are not the real basis of after-ripening but rather accompany or result from the loss of the dormant condition and from the start of the process of germination.

The factor or factors causing the dormancy of the embryo in junipers is unknown. In many species possessing dormant embryos, the excised non-after-ripened embryo will grow, however the excised embryo of red cedar will not grow (2).

Several investigators have outlined procedures for the nurseryman to follow in order to secure a good germination of the seed of red cedar.

Afanasiev and Cress (2) recommend collection as soon as the berries become ripe, cleaning the seed, and out-of-doors stratification. Chadwick (13, 14) recommends removal of the waxy coat of clean seed in December, using either alcohol or hot water, stratification at 35 to 41° F. until about April 1, and planting the after-ripened seeds in seed beds containing sandy soil. Miss Barton (6) has recommended late spring or summer planting of clean seed or the fall planting out-of-doors if the seed are soaked for 30 minutes in sulfuric acid. The seeds become after-ripened during the winter and germination occurs in the early spring.

PROPAGATION BY CUTTINGS. An evaluation of the literature of the rooting of cuttings is extremely difficult because of the lack of uniformity in the environmental conditions maintained by the different investigators and because of the variability of the cutting wood from year to year and from place to place. In many instances, also, not only are the conclusions based on a relatively small number of cuttings, but also considerable significance has frequently been ascribed to relatively small differences between the results of different treatments.

Among the numerous considerations of the cutting material which may markedly affect the ability of cuttings to root, only two have received any degree of attention. First, the age of the wood at the base of the cutting has been investigated. Wyman (60) reported that the presence of a small heel of two-year wood was of no significance for the four junipers studied (*J. chinensis pfitzeriana, J. horizontalis plumosa, J. sabina,* and *J. virginiana tripartita*). Longley (37) reported a slightly better rooting of *J. communis depressa* if the base of the cutting was of one-year wood. Chadwick (8, 9, 10) reported that a heel of two-year wood did not aid materially the production of a better root system for *J. horizontalis* and some of its varieties, but that cuttings with a two-year heel produced a better root system for the Irish juniper (*J. communis hispanica*), Greek juniper (*J. excelsa stricta*), Sargent's juniper (*J chinensis sargentii*), and *J virginiana tripartita.*

The second consideration of the cutting material is the time of the year the cuttings are made. There is marked agreement of the data of the various investigators that juniper cuttings taken from November through February root better than if taken at other times (20, 35, 58, 59). For example, Wyman (59) has reported the following rooting for the Andorra juniper (*J. horizontalis plumosa*): August, 65%, September, 52%, October, 91%, December, 100%; February, 96%, April, 33%, and June, 2%.

The affect of a basal wound on the rooting of juniper cuttings has been reported only for Pfitzer's juniper. Swartley (53) reported that a "light" wound increased the percentage of cuttings rooting from 4 to 24% and the use of Hormodin #3, in addition to the wounding, resulted in 52% rooting. It can be wondered whether or not wounding would be of benefit to other types of junipers.

The effects of chemicals, especially of the various growth regulators, have received more attention by investigators than any other aspect of the propagation of junipers. Several excellent tabulations are available (4, 41, 56). No attempt will be made to review all of these papers, but rather to discuss some of the more significant points of the effects of root-promoting chemicals with reference to juniper cuttings.

Early investigations showed that cuttings of the Andorra juniper (7, 8, 9, 10) of Pfitzer's and Sabines junipers (35) treated with potassium permanganate resulted in an increased percentage of cuttings with roots. Glucose also increased the percent rooting (35).

Early in the study of the effects of indoleacetic acid (IAA), indolebutyric acid (IBA), naphthalenacetic acid (NAA), and similar compounds on the rooting of cuttings, many investigators studied the responses of the various junipers. One of the earliest reports is that of Oliver (43) on *Juniperus sabina.* In 52 days, he obtained 60% rooting following soaking the base of the cuttings in 100 parts per million of IBA, but in contrast no rooting was obtained with the untreated control cuttings. Several of the more comprehensive investigations with respect to a number of different types of junipers and to the range of effective concentrations of the growth substances are those of Doran (24), Maxon, Picket, and Richey (39), Myhre and Schwartze (42), and Verleyen (58).

The rooting of many junipers is erratic—excellent percentages may be obtained sometimes, while much poorer results occur at others. In general, the spreading, prostrate forms can be rooted more easily than the upright forms. Probably the most difficult juniper to root is the Eastern red cedar (*J. virginiana*) and its numerous varieties.

The use of root-inducing chemicals will not take the place of good stock material nor of good cultural practices. Nor will the use of growth substances commonly stimulate the rooting of cuttings which ordinarily do not root. The junipers which are difficult to root are not, in general, greatly benefited by the use of a growth substance. If it is assumed that the naturally occurring hormone is limiting, then the use of synthetic materials should bring about an increase in the rooting response. However, with difficult to root materials, it is quite probable that other factors or conditions may also limit the ability of the cutting to initiate roots.

Chadwick and Kiplinger (20) found that use of IBA on Pfitzer's juniper cuttings resulted in a greater increase in rooting if the cuttings were taken during January or February than in November or December. Retreatment with IBA after a period in the propagation bench, brought about a slight increase in the percentage of cuttings rooting but not sufficient to make the practice economically significant.

Swartly (53) has reported that treatment of cuttings with root-inducing chemicals dispersed in talc was markedly decreased if the mixture was very acid (pH 3). Meahl (40) reported that wetting the base of the cutting in water or various strengths of alcohol prior to dipping the cutting in a talc-growth substance mixture did not increase the percentage of creeping juniper cuttings (*J. horizontalis*) to root. Recently Doran (25) has obtained a higher percentage of rooting of cuttings of *J. communis*, Pfitzer's juniper, and Eastern red cedar when treated with a fungicide (Phygon XL) alone or following the treatment with growth substance.

The use of the various synthetic growth substances definitely have a place in the rooting of cuttings of many kinds of junipers. However, many other forms are not markedly affected by present treatment practices and adequate rooting of these cuttings—sufficient to make the method economically feasible—must await additional investigation.

With regard to the method of watering the cuttings, it has been reported that overhead watering was more satisfactory than either constant or manual subirrigation for both Pfitzer's juniper and *J. virginiana Kosteri* (16).

Numerous investigators have compared the rooting of juniper cuttings in different rooting media. Pridham (48) has reported that both coarse vermiculite and cinders were superior to sand for Pfitzer's juniper, but Chadwick (16) reported little difference in the percent of cuttings rooted in bank sand and vermiculite. Chadwick (8, 10) has also reported that a mixture of sand and peat was best for the Andorra juniper and Long (36) stated that both *J. chinensis* and *J. horizontalis* produced a slender and more branched root system in sand and peat mixtures than in sand alone. Myhre and Schwartze (42) found sand to be a better medium than sand and peat mixture for the Irish juniper. Differences between the rooting response of cuttings of several junipers (*J. sabina, J. chinensis oblonga,* and *J. sabina tamaricifolia*) in sand and in sand and peat mixture were greater for those cuttings which were not treated with a growth regulator than for treated cuttings.

Large differences exist between the various rooting media with regard to capacity to hold water and with regard to aeration. In none of these experiments were these factors measured and it is quite probable that some of the differences found between the rooting response of cuttings in different media as well as between results for the same medium obtained in different years can be attributed to differences in watering. In all probability the rooting medium itself has very little direct affect on the rooting of cuttings.

Chadwick (17) found that under continuous illumination supplied by fluorescent lamps, the percent of Pfitzer's cuttings rooting was less than under natural daylight, however the rooting was more rapid under the continuous artificial light. The intensity of the artificial light, as well as the total energy received by the cuttings, was considerably less than that of the natural daylight.

PROPAGATION BY GRAFTING. Mallison (38), in 1926, wrote in the *Florists' Exchange* that more than 30 of the species and varieties of junipers listed in the catalogues of American nurseries were propagated by grafting. The Eastern red cedar (*Juniperus virginiana* L.) was used as the understock. He discussed procedural details for the use of a side graft.

Esper (27) has presented data concerning the influence of the understock on the establishment of cion- and union-roots on deeply planted junipers. Three varieties of *Juniperus virginiana—Canaertii, Kosteri,* and *glauca*—were used as the cions. He reported that a greater percent of the grafts developed roots from the cion and area of graft union if the Chinese and Greek junipers were used as the understock. The lowest percent of grafts with cion roots resulted when the understock was Oriental arbor vitae (*Thuja orientalis*).

Both Chadwick (15, 18) and Chandler (22) have discussed the value of various understocks for junipers. Chadwick's information was based on measurements and other characteristics of growth of commercially grafted plants. He rated the understocks as follows: Eastern red cedar, best; Chinese juniper, satisfactory; Andorra, Irish, and Spiny Greek junipers, fair or fair to poor; and Oriental arbor vitae, poor. Chandler's comments were based on years of experience of grafting and growing junipers. He rated the Eastern red cedar as the best understock and the Oriental arbor vitae as the poorest. *J. chinensis* was considered to be acceptable for varieties of the species. The Andorra juniper (*J. horizontalis plumosa*) produces a dwarfing effect and the plant declines in vigor within a few years and develops blight. His experiences with the Greek and Irish junipers as understock were unsatisfactory.

In a recent issue of the Ohio State Nursery Notes, Chadwick (19) has reported a high degree of success for five varieties of junipers grafted on red cedar understock and carried on open benches under conditions of high humidity. Grafts which were not waxed were as successful as those which were waxed.

In 1951, Keen (33) presented a progress report of his experiments using "cutting-grafts" as a means of obtaining own-rooted lining out stock of two difficult to root varieties of *J. virginiana.* The "cion-cutting" was grafted one inch above the base of the "stock-cutting" and the union was covered with a coarse grade of vermiculite. He reported 68% rooting of the stock on which was grafted *J. virginiana Burkii* (on the plant known in the nursery trade as *J. glauca Hetzii*) and 64% rooting of the stock used for *J. virginiana Kosteri* as cion (on *J. horizontalis plumosa*). Incidentally, when the stocks were cut back, they were restuck in order to obtain rooting and to be usable as regular understocks another year.

Although many junipers are propagated by grafting, there has been relatively little experimental work on this method of propagation, and it would seem that additional experimentation could add considerable information of value to the propagator.

BIBLIOGRAPHY OF PROPAGATION OF JUNIPERS

1. AFANASIEV, M. & M. CRESS. 1942. Changes within the seeds of *Juniperus scopulorum* during the process of after-ripening and germination. *Jour. Forestry* 40:798-801.
2. ——— & ———. 1942. Producing seedlings of red cedar (*Juniperus virginiana* L.) *Okla. Agri. Exp. Sta. Bull.* 256:1-21.
3. AMLONG, H. W. & G. NAUNDORF. 1938. *Die Wuchshormone in der gärtnerischen Praxis.* Nicolaische Verlagsbuchhandlung. Berlin. 157 pp.
4. AVERY, George S. Jr. & Elizabeth B. JOHNSON, with others. 1947. *Hormones and Horticulture.* McGraw Hill Book Co. New York. 326 pp.
5. BANNAN, M. W. 1942. Notes on the origin of adventitious roots in native Ontario conifers. *Amer. Jour. Bot.* 29:593-597.
6. BARTON, Lela V. 1951. Germination of seeds of *Juniperus virginiana* L. *Contri. Boyce Thompson Inst.* 16:387-393.
7. CHADWICK, L. C. 1929. Root development aided by chemicals. *Florists' Rev.* 65(1673):23-24.

8. ———. 1930. The influence of chemicals, media, and the position of the basal cut on the rooting of evergreens and deciduous softwood cuttings. *Proc. Ann. Meet. Amer. Plant Propagators Assoc.* 1930:11-36.

9. ———. 1930. Studies in propagation. *Florists' Rev.* 66(1691):29-30.

10 ———. 1933. Studies in plant propagation. The influence of chemicals, of the medium, and of the position of the basal cut on the rooting of evergreen and deciduous cuttings. *New York (Cornell) Exp. Sta. Bull.* 571:1-53.

11. ———. 1937. Test chemicals in rooting cuttings. *Amer. Nurseryman* 66:7-9.

12. ———. 1937. Effect of synthetic growth substances on rooting of cuttings of woody ornamental plants. *Ohio State Univ. Nursery Notes* 7:1-11.

13. ———. 1946. Seeds of red cedar. *Amer. Nurseryman* 83(9):10.

14. ———. 1946. Handling seeds of red cedar. *Ohio State Univ. Nursery Notes.* 15:11.

15. ———. 1948. Juniper understocks. *Amer. Nurseryman* 87(5):74.

16. ———. 1949. The effect of certain mediums and watering methods on the rooting of cuttings of some deciduous and evergreen plants. *Proc. Amer. Soc. Hort. Sci.* 53:555-566.

17. ———. 1949. Some results with the use of opaque structures for propagation by cuttings. *Proc. Amer. Soc. Hort. Sci.* 53:567-572.

18. ———. 1951. The influence of several understocks on the growth of scions of some varieties of *Juniperus*. *Proc. Amer. Soc. Hort. Sci.* 58:301-307.

19. ———. 1953. Some propagation studies—juniper grafting. *Ohio State Univ. Nursery Notes.* 22:3-4.

20. ——— & D. C. KIPLINGER. 1938. The effect of synthetic growth substances on the rooting and subsequent growth of ornamental plants. *Proc. Amer. Soc. Hort. Sci.* 36:809-816.

21. ——— & John C SWARTLEY 1941 Further studies on the effects of synthetic growth substances on cuttings and seeds. *Proc. Amer. Soc Hort Sci.* 38:690-694.

22. CHANDER, C. A. 1948. Types and values of understocks. *Amer. Nurseryman* 87 (10):12.

23. COWART, F F. & E. F. SAVAGE. 1944. The effect of various treatments and methods of handling upon rooting of Muscadine grape cuttings. *Proc. Amer. Soc. Hort. Sci.* 44:312-314.

24. DORAN, William L. 1941. The propagation of some trees and shrubs by cuttings. *Mass. Agri. Exp Sta. Bull.* 382:1-56.

25. ———. 1952. Effects of treating cuttings of woody plants with both a root-inducing substance and a fungicide *Proc. Amer. Soc. Hort. Sci.* 60:487-491.

26. EASTMAN, R. E. 1911. News and notes. *Forestry Quart.* 9:173-174.

27. ESPER, Harold. 1932. Juniper understocks. *Florists' Rev.* 69 (1794):82.

28. EVENARI, Michael. 1949. Germination inhibitors. *Botanical Rev.* 15:153-194.

29. GERBRACHT, J. W. 1937. Evergreens from seeds. *North and South Dakota Hort.* 10:46, 48.

30. HERBST BROTHERS. 1949. Catalogue of Seeds for Nurserymen. New York 36 pp.

31. HITCHCOCK, H. E. & P. W. ZIMMERMAN. 1939. Comparative activity of root-inducing substances and methods for treating cuttings. *Contri. Boyce Thompson Inst.* 10:461-480.

32. JELLEY, M. E. 1937. Eastern red cedar. *Jour. Forestry* 35:865-867.

33. KEEN, Ray A. 1951. Cutting grafts of juniper: a progress report. *Proc. Amer. Soc. Hort. Sci.* 58:298-300.

34. KIRKPATRICK, Henry Jr. 1940. Rooting evergreens with chemicals. *Amer. Nurseryman* 71(8):9-12.

35. KLEIN, Irwin. 1931. Rooting response of conifers to treatments with organic and inorganic compounds. *Proc. Amer. Soc. Hort. Sci.* 28:447-451.

36. LONG, J. C. 1932. The influence of rooting media on the character of roots produced by cuttings. *Proc. Amer. Soc. Hort. Sci.* 29:352-355.

37. LONGLEY, L. E. 1938. Effect of growth substances and maturity on rooting of cuttings of certain shrubs. *Proc. Amer. Soc. Hort. Sci.* 36:827-830.

38. MALLINSON, J. W. 1926. Grafting rhododendrons and choice conifers. Part III. Junipers. *Florists' Exchange* 61:749-751.

39. MAXON, Marcus A., B. S. PICKETT, & H W. RICHEY 1940. Effect of Hormodin A, a growth substance, on the rooting of cuttings. *Iowa State College Research Bull.* 280:931-973.

40. MEAHL, R. P. 1939. Effect of pretreating evergreen cuttings with alcohol before using root-promoting substances in powder form. *Proc. Amer. Soc Hort. Sci.* 37:1105-1108.

41. MITCHELL, John W. & Paul C. MARTH. 1947. *Growth Regulators.* Univ. Chicago Press. Chicago. 129 pp.

42. MYHRE, Arthur S. & C. D. SCHWARTZE. 1948. Rooting evergreen cuttings with hormones. *Proc. Amer. Soc. Hort. Sci* 51:639-650.

43. OLIVER, R. W. 1938. Preliminary tests with plant hormones in the rooting of greenwood cuttings. *Scientific Agric.* 18:379-387.

44. PACK, Dean A. 1921. After-ripening and germination of *Juniperus* seeds. *Botanical Gazette.* 71:32-60.

45. ———. 1921. Chemistry of after-ripening, germination, and seedling development of juniper seeds. *Botanical Gazette.* 72:139-149.

46. PARKER, Johnson. 1950. Germination of Eastern red cedar seeds. *Jour. Forestry* 48:255-256.

47. POESCH, G. H. 1938. Effect of growth substances on the rooting of woody ornamental plants. *Ohio Agri. Exp. Sta. Bimo. Bull.* 191:56-62.

48. PRIDHAM, A. M. S. 1948. Comparison of quartz sand, cinders, and vermiculite in rooting of evergreen cuttings. *Proc. Amer. Soc. Hort. Sci.* 51:657-658.

49. SEN GUPTA, J. N. 1936. Seed weights, plant percents, etc., for forest plants in India. *Indian Forest Rec.* (ns) 2:175-221.

50. SHEAT, Wilfred G. 1948. *Propagation of trees, shrubs, and conifers.* MacMillan Co., London. 479 pp.

51. STEAVENSON, H. A. 1940. The hammer mill as an important nursery implement. *Jour. Forestry* 38:356-361.

52. STOECKELER, J. H. & L. C. BASKIN. 1937. The Denbigh disc scarifier, a new method of seed treatment. *Jour. Forestry* 35:396-398.

53. SWARTLEY, John C. 1940. Further experiments on the rooting of evergreen cuttings. *Ohio State Univ. Nursery Notes.* 9:5-12.

54. ——— & L. C. CHADWICK. 1939. Synthetic growth substances as aids to root production on evergreen and softwood deciduous cuttings. *Proc. Amer. Soc. Hort. Sci.* 37:1099-1104.

55. SWINGLE, C. F. 1937. A promising new cedar for erosion control. *Soil Conserv.* 3:75-78.

56. THIMANN, Kenneth V. & Jane BEHNKE. 1947. *The use of auxins in the rooting of woody cuttings.* Maria Moors Cabot Found. Publ. 1:1-272. Harvard Forest, Petersham, Mass.

57. TOUMEY, J. W. & C. F. KORSTIAN. 1942. *Seeding and planting in the practice of forestry.* 3d ed. J. Wiley & Sons. 520 pp.

58. VERLEYEN, E. J. B. 1948 *Le bouturage et les substances de croissance synthetiques.* Antwerpt.

59. WYMAN, Donald. 1930. The time of year to make cuttings of narrow-leaved evergreens. *Florists' Exchange* 75 (11):27.

60. ———. 1930. The influence of the heel in the rooting of narrow-leaved evergreen cutting. *Florists' Exchange* 75(14):25.

61. ———. 1947. Seed collection dates of woody plants. *Arnoldia* 7:53-56.

62. WATKINS, J. V. 1938. Further data on response of cuttings to Hormodin A. *Southern Florist* 45(25):5-8.

63. WEBSTER, C. G. & George T. RATLIFFE. 1942. A method of forcing quick germination of *Juniperus virginiana* L. seed. *Jour. Forestry* 40:268.

64. YERKES, Guy E. 1932. Propagation of trees and shrubs. *USDA Farmers' Bull.* # 1567.

65. ———. 1938. Treat cuttings with indolebutyric acid. Results of tests with cuttings of trees and shrubs made at the United States Horticultural Station at Beltsville, Md. *Amer. Nurseryman* 67(9): 10-11.

* * * *

PRESIDENT WELLS: Before we get on to the questions, I would like to comment very briefly on wounding.

In 1946, I was at Boskoop and there ran into the question of wounding for the first time. They have been experimenting on the trial ground in Boskoop for over 10 years now in all aspects of propagation and with particular reference to junipers. They have quite a stack of published data which boiled down comes to this: that they prefer to take young wood without heel and with a light wound and treat with hormone in powder form. We, after experimentation and with that data, arrived at similar conclusions. We found that wounding was very definitely of value. Without wounding, one, two, or three coarse roots form on the base of the cutting, but with a wound a fine bunch of roots develop. If the wound was applied twice, a completely balanced root system develops.

CHAIRMAN SNYDER: Will you describe the wounding operation?

PRESIDENT WELLS: A light wound is made by running the blade of a knife along the base just cutting through the outer bark.

First, we tried a wound on one side, but we finally came to using two wounds—on opposite sides of the cutting.

I would like to ask one question. What was the cutting understock used in the cutting-graft experiments?

CHAIRMAN SNYDER: The understocks were *Juniperus virginiana Burkii* and the Andorra juniper (*J. horizontalis plumosa.*) Incidentally, Mr. Keen is here and I hope I haven't misrepresented his paper which was made as a progress report. I asked him the other night why he had not published further information and he replied that there was a very good reason. The material was lined-out in the field but that the material ended up three feet under sand as a result of serious floods in Kansas. He started the work over and is carrying it on. He hopes to publish additional information not too far in the future.

MR. TOM KYLE (Tripp City, Ohio): Has anyone in the room had any conclusive experience with *Juniperus glauca Wetzii* as an understock?

MR. RAY A. KEEN (Ohio State University, Columbus, Ohio): At the time I was doing the work with the cutting-grafts, the nurseryman who furnished me that matérial tried some experiments on his own with Hetzii stock. He was running short on stocks and he planted out a block that was on Hetzii and another small block on Andorra, using two or three different kinds of junipers as scions. The material on Andorra was very markedly dwarfed and the survival in the field was quite low. The survival on Hetzii was good but there was a loss of about a year in producing a finished stock. It took at least one additional year to get them to three feet.

MR. LESLIE HANCOCK (Woodland Nurseries, Cooksville, Ontario): Does the scion finally produce a certain amount of roots of its own?

MR. KEEN: On my work, it hadn't at the time it was lined out in the field. Regarding the other work I didn't see any of the stock after it was dug.

CHAIRMAN SNYDER: Espers' work seemed to indicate that with the exception of grafts on the Oriental arbor vitae, the scion would develop on its own roots. Of course, these were limited trials.

MR. MARTIN VAN HOF (Rhode Island Nurseries, Newport, R. I): I would like to comment on the understock of the Andorra. We have been grafting on Andorra in Newport quite extensively. In the East it really works fine, but in dry ground the plants on Andorras, soon die because it is shallow rooted.

Then I would like to comment on the seed of juniper. The procedure we go through for cleaning the seed is by mashing the pulp or seed and floating it, by floating the hull dead seeds are easily removed. After that is done we dry our seed just a little bit so it can be handled and sow by broadcast in outdoor.

CHAIRMAN SNYDER: What time of year?

MR. VAN HOF: In the fall, germination occurs in the spring. Then if you have sandy soil, it really pays to plant out the next year so that in two years' time there is a wonderful understock.

DR. R. F. CARLSON (Michigan State College, East Lansing, Mich.): In your review on the literature did you find any results or any work done on the inner relationship of light and temperature as influencing rooting, or light alone, for instance?

CHAIRMAN SNYDER: I did skip that in the presentation of the work of Chadwick comparing the rooting of juniper cuttings under constant fluorescent light in contrast to natural daylight. He found there was much more rooting under the natural daylight conditions than under the continuous fluorescent light, although those that rooted under continuous light rooted more rapidly. There is a great difference in the quality and quantity of light which was available under these two conditions. Chadwick did not say that the conditions were equal but rather he was attempting to show that cuttings could be rooted under continuous light of low intensity, but that the rooting response was not as good as under natural daylight greenhouse condition. When you are concerned with light it is hard to get strictly comparative conditions.

MR. HOOGENDOORN (Hoogendoorn Nurseries, Newport, R.I.): We had a peculiar incident a couple of years ago and I was wondering if you could explain why this happened? We had junipers which were well rooted by spring. During the latter part of March or the beginning of April they commenced to dry up. At first, we didn't pay much attention to it. There might have been a dry spot here and there. I started watching them. They kept drying. Finally, we planted out those which were left and they kept dying in the beds. By fall we didn't have ten percent left. Would you give us a reason for that?

CHAIRMAN SNYDER: Since the material began to dry up during the time the cuttings were in the bench, as well as later, it is suggested that something may have happened prior to making the cuttings or possibly shortly after the cuttings were inserted and before rooting occurred. It has been my observation that some years junipers tend to dry up when kept in an open bench or even under double glass whereas other years there is little or no drying. It is known that many plants are killed as the result of a loss of as little as fifteen to twenty per cent of the moisture content. It is possible that the cutting material was deficient in moisture when the cuttings were made or that loss of water from the cutting was more rapid than intake of water by the cutting. This can occur even though the medium is kept moist and the cuttings syringed frequently.

MR. VAN HOF: The tissue seemed to be in satisfactory condition at the time the cuttings were made and the medium was kept well moist.

CHAIRMAN SNYDER: In our work at Cornell we have found it extremely difficult to estimate water loss of both deciduous hardwood material and of narrow-leaved evergreen material. This is especially true until the water loss is quite high—twenty-five to thirty percent. When tissues dry out there are many changes which occur within the plant and within the individual cells which bring about a gradual death of the tissue. This is true even though the tissue may subsequently regain the moisture. In other words, the loss of water has set the stage for the death of the tissue, but the harmful effects do not show up for a considerable period of time With the cuttings which rooted and died later, it is possible that even though there was sufficient moisture in the base of the cutting for rooting to occur, the harmful effects of the drying eventually resulted in the inability of the stem to allow enough water to go up the stem to keep the tissue alive and functioning normally.

MR. RAY KEEN: Two years ago we had considerable difficulty with both juniper grafts and cuttings in Kansas. We attributed a lot of the drying out to early winter damage. That particular year we had very sudden temperature drops and we got a lot of this dying back that you mentioned. Frequently the base of the cutting came ahead, but the cutting died from the tip back.

MR. LESLIE HANCOCK (Woodland Nurseries, Cooksville, Ontario): We have also had difficulty in juniper cuttings dying back. In my opinion we had juniper blight. If you ever get juniper blight in the stock it will be carried over into the cutting beds and you will continue to get dying. In recent years we have not lost any because our cuttings came from very healthy stock. Another time we lost a lot of stock, but that time we found white grub in the beds.

CHAIRMAN SNYDER: Gentlemen, I suggest that we postpone additional discussion until the open discussion period which follows the other two papers on the commercial practices of juniper propagation.

I have been asked to announce that the report of the Nominating Committee is here on the rostrum. It is available to anyone who wishes to look at it. The formal report will be presented Saturday morning at the business meeting, at which time nominations from the floor will be in order. If you wish to see who has been nominated by the Nominating Committee, the report will be available at the close of this session.

As Mr. Wells told you at the beginning of this session, we thought that since there were a considerable number of requests for a bibliography and backlog information brought up-to-date on the propagation of these various materials that we would start each of our panels by a review of literature and then follow with the practices that are actually used in the commercial procedures.

We have selected good men for each of our topics, men who have had considerable experience with the plant and the method. Also, we have tried to select people who were not on the program in previous years and I presume, subsequent program committees will follow that procedure in order to give all of us an opportunity to speak about plant propagation.

I really think there is no point in making any special remarks about our next speaker. You know him very well. He is going to speak to you on Junipers from Cuttings. Mr. Pieter G. Zorg, Fairview Evergreen Nursery, Fairview, Pennsylvania.

MR. PIETER G. ZORG: Thank you, Dr. Snyder, Ladies and Gentlemen: When I received the invitation from Dr. Snyder to talk about junipers from cuttings I was a little bit suprised to find that you selected one of the topics to be propagation of junipers.

Mr. Zorg presented his paper, entitled "Propagation of Junipers from Cuttings." (Applause)

The Propagation Of Junipers From Cuttings

Pieter G. Zorg

Fairview Evergreen Nurseries, Fairview, Pennsylvania

One of the most convenient ways to propagate Junipers in large variety is by means of cuttings. This has been done for a great number of years in Europe as well in the United States. The purpose of growing Junipers from cuttings is quite obvious: to multiply a chosen plant and retain all its characteristics. It ranks among one of the most effective methods of increase for a large selection of Junipers. Some species and varieties are easily propagated by cuttings, while others require a little more attention, and some are difficult, but the method prevails because of its economy in handling. Besides, there is the advantage which is obtained by having the plant on its own roots.

It is not necessary to have a greenhouse for rooting Juniper cuttings; it can be done in a coldframe as well. In France the nurseryman uses bell jars, which is more or less an ancient way of propagation in our eyes and commercially unpractical.

In Germany coldframes are used. About 6 inches of horse manure is placed in the bottom of the frame. When watered down, this horse manure is a heat producing medium. On top of this 4 to 6 inches of soil, while the top layer consists of 4 inches of sand. In this sand the cuttings are inserted. The cuttings are taken in August, with a heel, and remain in the frame the following year and taken out in the spring of the second year. This whole process thus takes almost 2 years.

In Holland propagation of Junipers by cuttings is done in the same manner, with exception of the use of horse manure. Here sometimes straw is the material which is used for the heating medium, or an electric cable. The final result can be very good, although it usually will be less, than with the use of a greenhouse.

Since greenhouses in Holland and Germany are generally employed for grafting purposes the year around, it is considered too expensive to use them for evergreen cuttings. Here in the United States we commonly have greenhouses available for the propagation of Junipers.

Medium:

The medium commonly used is sand. The texture of this sand should be rather coarse. Coarse sand promotes the aereation better than fine sand does, so the first should be preferred. There is not a rule without an exception however, there have been successful batches of cuttings grown in fine lake sand. It is questionable whether sand is the best medium at all. Mixtures of peatmoss and sand promote a good root system also. I shall refer to this a little later.

To prevent fungus growth, it is advisable to renew the sand each year.

Size of the cuttings:

Cuttings should be made approximately 6 to 7 inches tall. In the South cuttings are taken much taller than this, but it is harder to grow a shapely plant from these cuttings. In order to grow a plant, which branches from the base, cuttings 6 to 7 inches tall are of the most desirable size.

The Europeans and some nurserymen in the United States prefer heel cuttings. These are cuttings stripped off the plant, so that a small slice of the older branch is attached at its base. It might have some advantage to make heel cuttings when they are grown in a frame, but for growing in a greenhouse with bottom heat, cuttings without a heel do just as well There is also some controversy among nurserymen, as to which tool to use in preparing the cuttings; knife or clippers. In my estimation, both work just as well. More is accomplished in the course of a day however, when clippers are used.

Time:

Proper timing is very important in taking cuttings. It is difficult to give an exact date when the material is in the right condition, so the best results can be expected. This depends a great deal on the weather. During a period of heat and drouth, after a period of rain, plants will quit growing and will be ripened off soon. On the other hand, when the rain comes more evenly over the whole season and the temperature is more constant, plants will keep on growing, and ripen off later. It is self evident that this has a great influence on cutting material. As a general rule, the proper time to take Juniper cuttings coincides with the time plants stop growing, at the time plants start to grow, and never in the middle of the growing period. When Juniper cuttings are grown in a frame the time to take them is about the latter part of August or the beginning of September. This is the time when the growth is about completed. Some growers like to prepare Juniper cuttings in early summer. It can be done and the results can be satisfactory, but the time of late August or the beginning of September is considered better.

Propagation in the greenhouse, which is the usual procedure in the United States starts in November for Junipers. The cuttings are prepared in the workroom and care should be taken that they do not dry out. They are inserted in the bench, at about ¾″ by 2″. This will amount to about 100 per square foot. The sand should be watered thoroughly before the cuttings are placed and then firmly packed.

Watering:

In the fall and winter, when the sky is cloudy many times, it is advisable to be very careful with watering. The sand never should be dry, but on the other hand, when too much water is applied and the sand is saturated, the conditions are ideal for fungus growth. This should be prevented, for fungi can do a great deal of harm to a bench of cuttings. It can destroy thousands of cuttings overnight. As soon as fungus is spotted, it is best to open the ventilators to let fresh air in and watering should be omitted. Avoid watering in the afternoon. The first 8 to 10 weeks are the most critical, and at this time utmost care should be taken as far as watering is concerned.

When the cuttings commence to make new growth, it indicates that roots are forming. This will be about the case in February or March. At this time of the year the sun's rays are warmer and will increase the temperature in the greenhouse. More water can be applied, for the sand will dry out faster and the roots will take up more moisture. It could be necessary also that at this time some whitewash should be applied to the outside of the greenhouse to prevent the sun from burning the cuttings. At first a light application will be sufficient, while later a heavier coat of whitewash should be put on. By the 15th of May the cuttings will be ready to be planted in a field with irrigation. When potting is preferred, this can be done earlier and the pots plunged in a frame with shade frames overhead.

Use of hormones:

It is advisable to use a rooting stimulant for Juniper cuttings. Hormodin No. 2, in powder form, which contains 0.3% indolebuteric acid will generally be sufficient, but for the varieties which do not root readily, Hormodin No. 3 which contains 0.8% indolebuteric acid will be better.

Which species and forms of Junipers are generally rooted:

Of all the Junipers, the species *Communis* consists of most of the forms which can be propagated by means of cuttings. To name a few: *Juniperus communis depressa* and the forms aurea and Vase Shaped, *Juniperus communis montana, Juniperus communis hibernica* and the form fastigiata, and *Juniperus communis suecica* and *J. c suecica nana*. Another species which roots very well is *Juniperus conferta. Juniperus horizontalis* and the variety *plumosa* (Andorra Juniper) strike very good from cuttings. Also *Juniperus Sabina* and the variety *tamariscifolia* do well. The latter is not grown very much any more, because it is susceptible to blight. In the species *chinensis* are many varieties which can be propagated by cuttings, but there are more which have to be grafted. One of the easiest is *Juniperus chinensis glauca Hetz,* a plant originated at the Fairview Evergreen Nurseries. A result of 90-95% rooted cuttings is common. It is different with *Juniperus chinensis Pfitzeriana* and its forms aurea and glauca however. These Junipers can really be troublesome. The best way to handle them thus far, is to make the cuttings early, that is in September. Then take them up in January and re-stick them. This shock seems to encourage root formation. It is also advisable to use Hormodin No. 3 on these cuttings. *Juniperus chinensis Sargentii* is another one hard to handle. *Juniperus chinensis Keteleeri* is usually grafted, but I believe that this form can be propagated from cuttings. Last year I had a result of 64%. *Juniperus virginiana glauca* gave me 53%. These results are not very striking, but I am very sure that with some experimenting this can be increased. Maybe spring cuttings under a fog line is the answer. Most of the virginiana forms are propagated by means of grafting.

Juniperus squamata Meyeri is a very attractive plant, which does not give much difficulty in propagation by cuttings. Hormodin No. 2 will generally be sufficient to make them root.

Since many nurserymen complain that grafted junipers are short-lived, and the general trend is toward plants on their own roots, it should be our aim to propagate junipers from cuttings as much as possible. There are still a number of junipers which cannot be rooted or are hard to root from cuttings. But in the future, with the aid of the several hormones and modern equipment, it may be possible to propagate all of the junipers on their own roots. As I mentioned before, spring cuttings and the fog line or a different rooting medium might do it. It is very interesting to read what the research workers are doing in Boskoop, Holland. They are trying out various media (peat moss and sand in several mixtures) and liquid hormones. Here are some of the results they have obtained:

Cuttings of *Juniperus chinensis Pfitzeriana* were inserted in a mixture with double sash in October. A mixture of peat moss and sand (two to one) was used and the cuttings were treated with alpha naphthaleneacetic acid (50 mg. per liter of water). In March of the following year, 85 percent were rooted.

Cuttings of *Juniperus chinensis Pfitzeriana* were inserted in a mixture of peat moss and sand (three to one) in a greenhouse on November 1. On January 17, 93 percent of the cuttings were rooted. The cuttings were wounded at the base.

Cuttings of *Juniperus squamata Meyeri* were wounded and soaked for 24 hours in 50 mg. indolebutyric acid per liter of water before inserting in a medium consisting of peat moss and sand (two to one). Within less than three months, 100 percent of the cuttings were rooted. Use of a double strength indolebutyric acid solution gave the same result.

Good results can be obtained with junipers which are generally regarded as difficult to root. Wounding at the base seems to be an important procedure.

* * * *

CHAIRMAN SNYDER: Pieter Zorg did an excellent job and I am certain that all of us are very pleased with his presentation. There are about eight minutes for questions and discussion.

MR. ROSCOE A. FILLMORE (Fillmore's Valley Nursery, Nova Scotia): I have tried a number of times to root Pfitzer's juniper cuttings in sandy soil without success. I would like to hear of some of the experiences of others along this line.

MR. ZORG: I have never rooted junipers in sandy soil. I have tried junipers in sand and in sand and peat moss of various mixtures. I have also tried it in vermiculite which was not satisfactory. With Pfitzer's juniper in sand, I occasionally put them in early, in September, take them up in January, and restick them. Last year I had wonderful results with it.

MR. ROSCOE FILLMORE: Do you retreat the cuttings in January?

MR. ZORG: No, I don't retreat. I take them out and set them in right away. I don't put any powder on them any more at all.

MR. ROLLER (Verhalen Nursery Co., Scottsville, Texas): All of our propagation, as I have said before, is in sandy soil. We don't use sand and peat mixtures or vermiculite. Our cuttings are being stuck at the present time. (Editor's note: early December.)

In Texas, we can stick Pfitzer juniper cuttings any time from the middle of November to the middle of February, just before the plants start to grow, and expect the same results or, possibly, a little better results from the February group. Year in and year out, we consistently get averages of around eighty percent rooting by just sticking these cuttings in our sandy soil and covering with lath.

Of course, peat moss has been worked into the soil. As I said yesterday, these beds have one medium size bale of peat moss spaded into approximately 160 square feet of bed space and then an additional bale of peat moss is added after each crop is removed. We never retreat the cuttings and so far we have not used wounding.

MR. JONES (Passaic, N. J.): Have you had any experience rooting the forms of *J. virginiana?* Do they make a good root system?

MR. ZORG: It is well known, of course, that Pfitzer's juniper is better when propagated by cuttings than by grafts. You probably will agree with that because the plant will grow much better when propagated from a cutting.

MR. JONES: What is the difference between *Pfitzeriana* and *glauca?* If you have any experience, I would like to know if they will survive and keep on growing well?

MR. ZORG: They will survive and keep on growing but I haven't had too much experience yet with glauca cuttings. I have made cuttings for the past three years only, and I don't know what the procedure will be after they are four, five, or six years old.

MR. HERBERT TRAUTMAN (Trautman Nurseries, Franksville, Wis.): We grew *J. virginiana* from cuttings in a limited amount about fifteen years ago. I believe we still have some of those original plants in the nursery—Dundees, glaucas, and all kinds of chinensis. They are growing well. They were grown in beds under a high lath shade. Although our percentages were low, we got enough to make it pay for our own use. We never tried to put them on a commercial basis. We can get *Keteleeri* very well, but we discontinued that plant because it is one of the plants that burns very easily up North.

MR. JACK HILL (D. Hill Nursery, Dundee, Ill.): We have tried *J. virginiana glauca* for a number of years and never got substantial results. I know for a fact that the Monrovia Nursery in California grows glauca because I have seen them there to a height of four feet. They seemed in good shape.

CHAIRMAN SNYDER: I think that it would be wise to defer additional questions until the discussion after the next paper. Thank you very much, Pieter, for a very excellent discussion on junipers from cuttings.

The record of D. Hill Nursery Company in the production of narrow-leaved evergreens is, alone, sufficient to recommend someone from that organization to discuss the grafting of junipers. We are glad to welcome Mr. Jack Hill to our meeting and are anxious to hear his discussion of grafting junipers.

MR. JACK HILL: Mr. President, Mr. Chairman, and assembled propagators: In the paper which I have prepared, I have not attempted to go into the history of grafting at all. There are repeated references in the literature to grafting that was done many hundreds of years ago. I believe there are actual references of it in ancient China where it was practiced on fruit trees. It was a recognized science at that time.

I have also concerted the efforts of this paper on the methods which are employed most generally throughout the United States, for example, I have not gone into trick bottle grafting nor the out-door grafting practice.

Mr. J. B. Hill presented his paper, entitled "Juniper Grafting—Practical and Technical Aspects." (Applause)

Juniper Grafting—Practical and Technical Aspects

J. B. Hill
D. Hill Nursery Co., Dundee, Illinois

The intent of this paper shall be, not to restate those basic fundamentals found in available literature, but to relate experiences from the standpoint of a commercial propagation effort. Special emphasis will be afforded those deviations from the standard procedures outlined in the literature. These deviations we have proven practical, and useful.

It should not be necessary to define a graft, let alone a juniper graft, but for the purposes of this paper, it shall be considered as "An organic union of two plants, as when a bud, or shoot containing a bud, is mechanically combined with another plant in such a manner that it lives and develops upon the food and nutrients supplied by the other."

The reasons for producing junipers by the grafting method are to enable the reproduction of those species and varieties that do not "come true" from seed, nor root readily as cuttings, and to insure vigorous shoot growth and plant development with those varieties proven to root so poorly as cuttings that this process is impractical from a commercial growers view.

The simple elements of a juniper graft are: the understock, the scion, the equipment, and the technique. These will be further enlarged upon in this order.

CHAIRMAN SNYDER: I think that it would be wise to defer additional questions until the discussion after the next paper. Thank you very much, Pieter, for a very excellent discussion on junipers from cuttings.

The record of D. Hill Nursery Company in the production of narrow-leaved evergreens is, alone, sufficient to recommend someone from that organization to discuss the grafting of junipers. We are glad to welcome Mr. Jack Hill to our meeting and are anxious to hear his discussion of grafting junipers.

MR. JACK HILL: Mr. President, Mr. Chairman, and assembled propagators: In the paper which I have prepared, I have not attempted to go into the history of grafting at all. There are repeated references in the literature to grafting that was done many hundreds of years ago. I believe there are actual references of it in ancient China where it was practiced on fruit trees. It was a recognized science at that time.

I have also concerted the efforts of this paper on the methods which are employed most generally throughout the United States, for example, I have not gone into trick bottle grafting nor the out-door grafting practice.

Mr. J. B. Hill presented his paper, entitled "Juniper Grafting—Practical and Technical Aspects." (Applause)

Juniper Grafting—Practical and Technical Aspects

J. B. Hill
D. Hill Nursery Co., Dundee, Illinois

The intent of this paper shall be, not to restate those basic fundamentals found in available literature, but to relate experiences from the standpoint of a commercial propagation effort. Special emphasis will be afforded those deviations from the standard procedures outlined in the literature. These deviations we have proven practical, and useful.

It should not be necessary to define a graft, let alone a juniper graft, but for the purposes of this paper, it shall be considered as "An organic union of two plants, as when a bud, or shoot containing a bud, is mechanically combined with another plant in such a manner that it lives and develops upon the food and nutrients supplied by the other."

The reasons for producing junipers by the grafting method are to enable the reproduction of those species and varieties that do not "come true" from seed, nor root readily as cuttings, and to insure vigorous shoot growth and plant development with those varieties proven to root so poorly as cuttings that this process is impractical from a commercial growers view.

The simple elements of a juniper graft are: the understock, the scion, the equipment, and the technique. These will be further enlarged upon in this order.

Understocks suitable for juniper grafting need to be selected on the basis of variety, age, size, apparent vigor, and, of course, availability Many varieties of juniper have been used for grafting understocks, but it is generally conceded in all the literature that two, J. *virginiana* and *J. chinensis*, are best. If an exclusive choice were to be made between these two varieties, most experiences would indicate that *J. virginiana* is the most suitable understock for the varieties of ornamental juniper most commonly reproduced by grafting. The principal disadvantage of this variety lies in difficulty of producing it consistently under nursery conditions. *J. virginiana* is susceptible to a form of foliage blight known technically as *Phomopsis Juniperivera*, but familiar to us all as just "the blight." Our records at Hill's show that we have been able to grow *J virginiana* for the requisite two or three years, less than 60% of the time, and we feel certain that even in those years where there was not enough blight evident in the seed beds to condemn the production, high bench losses followed if the disease was present at all. This consideration of the blight problem has led us to the production of *J. chinensis* for understock purposes, and to date, only the availability of suitable seed has limited this program. Experiments conducted by our firm many years ago indicated that we did not wish to produce or sell juniper grafts employing Biota, *J. excelsa stricta*, or *J. plumosa* as the understock. Latent incompatability would appear the limiting factor with the first two and simple lack of subsequent vigorous growth reason for eliminating the third. Prof. Chadwick has indicated in his studies of understock suitability, notable exceptions to the objections outlined, but for the purposes of commercial production, it is far better to plan an understock that is universally acceptable with all the varieties found in the grafting list. It is for this reason we have chosen to concentrate our efforts upon understocks of *J. virginiana and J. chinensis*. Both of these varieties are produced in Dundee, Illinois, by fall sowing upon a "well prepared bed." Most are of suitable grafting size at the end of two growing seasons and are selectively dug for potting in late October or November. The residual quantities left in the seedling beds are fertilized well and left to grow another year.

The seedling junipers that we select for understock purposes, are chosen mainly upon the basis of their stem diameter, and apparent vigor of top growth. Optimum stem diameter, for our purposes, falls between that of a thick and thin pencil and needs be straight without obvious cambium imperfections. Apparent vigor of the selected understocks is felt to be of great importance, for only the most vigorous plants of this relative small size can have stored the abundance of carbohydrate and starch requisite for the production of ample callus, essential to the healing process. After being dug from the beds, these selected understocks are again graded to assure uniformity, their roots trimmed lightly to facilitate potting, and the plants having extra long tops are cut back to a length that will enable the ultimate graft to be benched conveniently. These graded and prepared seedlings are then potted off into 2½" rose pots in a suitable, well mixed potting soil—this year into John Innes Compost—and plunged to pot level in a bench of peat. The houses in which these understocks are held will be kept cool and moderately dry for approximately thirty days, or until the last week of November or early December. Incidentally, this time can be shortened to ten or fifteen days under some circumstances. It is preferred that this initial thirty day period be thought of as one of rest, even though the stocks had probably received several sharp frosts before they were dug. This short rest can be considered the equivalent of a "winter" in the regions to the south of Illinois where the *J. virginiana* is so much at home. Following this period of rest, an "artificial spring" condition is simulated by the application of both moderate heat and water . . . heat to the level of 65° in the bench and sufficient water that all the plunged pots are adequately moist. Adequate moisture is difficult to describe or define accurately, but for this paper it may be considered that level where it is just possible to squeeze a few drops of free water from the peat plunging medium. Within seven to twelve days after the heat and water are applied, evidence of root action should become apparent, and within another week, most of the understocks should be at the level of activity considered by most, suitable for grafting. There is, in all honesty, a dearth of information upon this technical point in the literature, but recollections of conversations with other growers seem to indicate that most feel as we do at Hill's that the optimum level of plant activity for grafting is indicated by the presence of white root caps ¼ to ½ inch long. There appears to be a definite advantage to grafting junipers at this stage of understock activity, whether secured by the methods outlined early or late in the grafting season—December to March. Grafting percentages would seem to suffer somewhat if the time of grafting is delayed until the understock is in full flush of growth and the roots extended in white and secondary growth to the length of several inches. It would be useful perhaps, to note at this time, that it is considered best by most growers in this country to have understocks established in the pots at least six months before the grafting season. We at Hill's, quite frankly, have had no extensive experience with this method, as our results would appear to be satisfactory without the additional time of the understocks in pots. Tests are planned however to check with certainty for an advantage to one method over the other. Since early experience with juniper grafting was obtained many years before my own activity in the firm, a question about this method of potting in the fall before grafting, rather than the spring preceding, reveals that the former method was outlined as best by several Boskoop growers, and has been followed in Dundee without deviation until this time.

Selection of "suitable" scions has always been looked upon by propagators as having an equal bearing upon the success of a grafting operation as preparation of the understock. Certainly no exception can be taken to this holding save that when all the facets of juniper grafting for commercial trade are considered, it is impossible to overemphasize the need for careful, discriminating selection. Need it be pointed up that to produce ample callous, quick healing, and union firmly to the stock, the best scion will need to be selected from a parent plant that is in the very highest bloom of health and vigor; let alone one of exactly the strain within the variety that is to be reproduced? The juniper scion which would be considered ideal at Hill's is 9 to 12 inches long, of growth in the current season, and approximately the same diameter at the base as that of the understock to which it is to be grafted. If there is to be a variation in this scion base understock diameter, it has always been felt best to put the smaller scion upon a larger understock than the reverse. Save to indicate again the greatest necessity for careful selection of this scion from a parent plant free from disease, free from harmful insects, and in the very burst of healthy vigor, only one more factor need be considered, and that is the time of removing the scion from the parent plant in preparation for grafting. In pure theory, everything would point to the advantages of attaching the scion to the understock at the earliest moment possible following its detachment, and there can be no argument against this hypothesis Unfortunately, there are many factors which enter into this consideration when juniper grafting is done on anything approaching a commercial scale. In Dundee we are often faced with cutting much scion material when outdoor temperatures are at or below freezing, and these scions need to be stored for periods of two to twenty days before they are actually united with the understock. There would appear to us to be no difference whatsoever between the results secured with scions, thus stored, over those placed on the understock within hours of removal from the parent plant. The storage facility which is used for this necessary interval is attached to the greenhouse work areas, and during our months of use provides temperatures from 30° to 40°. The scions are supported off the floor on simple racks having an open wire mesh bottom and all are thoroughly watered down so that the humidity within this storage remains near 100%, regardless of the slight variations in temperature.

The mechanics of making the actual graft itself are quite simple, requiring as tools only a sharp knife, thread, and rubber or tape with which to bind the scion to the stock. The type of graft most commonly used with junipers is the veneer or flap graft

In making this style of graft, the understock is cut for 1½ inches parallel to the axis of the stem, about one third of the way through the diameter, and to approximately one inch above the pot soil line This cut leaves the veneer or flap somewhat more flexible than the remaining stem of the understock. The scion bark and cambium is sliced away on two sides for a length of 1½ inches at the base which is either left or recut to a blunt chisel shape. This cut portion of the scion is inserted into the cut made in the understock, and the blunt end of the scion pressed as far as possible into the bottom of this incision. The flap and scion are then bound tightly to the stock with whatever material for tying has been selected. It is thought that most propagators now prefer the flat rubber strips marketed for the purpose, though some are using paper grafting tape or the still older linen thread. In any event, the points requiring close attention are the juxtaposition of the cambium layers scion understock, and the security of the tie or wrap. This tying needs be done with accuracy and strength so that under no conditions can the scion move about within the cut made in the understock. Any movement at this point during the healing process delays that time when an actually physical union will be established and scion growth enabled with plant nutrients supplied by the understock. Any extension in the period necessary to establish this union is detrimental and should be avoided if optimum results are to be obtained. In the past, much attention has been given in literature to the necessity of "matching" exactly the two bands of cambium exposed by the cuts on the scion and understock. While we have conducted no scientific tests enabling direct comparison, it would appear that there are many factors having greater bearing upon success than this . . . we simply get them near to matched on one side at least and depend almost entirely upon that volume of callous produced at the blunt end of the scion to affect early and adequate union with the understock. The understock, having obviously a greater supply of stored carbohydrate, invariably produces a greater mass of callous than does the scion and it is this greater mass that more or less enfolds the scion along the major line of the graft Union along this major line is essential to the production of a strong graft that will have the greatest exchange of food and nutrients between scion and understock Many years ago it was standard practice with most propagators to paint or in one way or another, cover this entire union area with grafting wax. At Hill's we no longer use wax of any kind, though, again, no direct comparison tests have been made within time of recall and perhaps we would find it fruitful to conduct a test of this sort.

After the mechanical processes of making the graft have been completed, there are two accepted methods of handling which will enable healing and establishment of the union. They are: placing the graft vertical in a bench, plunged to above the union in moist peat, or laying the graft in the plunging peat at an angle of approximately 45° and covering the bench with a tight fitting sash. In either event, the temperature of the plunging medium should be kept constant at that temperature which will promote rapid and continuous healing of both understock and scion The advantages of the open bench method are obvious. A greater number of pots in any given size can be accommodated, day to day appearance of the plants can be more readily checked, and there is far less likelihood of invasion by pathogenic fungi or virus since the interval assured by the placing of the pots does not allow the tops of the plants to touch. The double glass or sweat box method needs far less daily attention since the complete restriction of air circulation negates the need for additional water to replace that lost through evaporation and transpiration. A close watch needs be kept however, for the first appearance of any mold or fungi, since under the conditions within the sweat box, these organisms spread with surprising rapidity. Any graft showing the slightest disease, must be taken from the bench immediately and either isolated away from the rest of the crop or destroyed. Failure to observe the first indications of this problem has cost us many plants in the past, as we have used the double glass method of healing almost entirely until this date. Trials have been made, however, with the open bench and we are quite certain that this newer method, with humidification equipment, will prove best. With mention of the word "humidification" it should be indicated that the temperatures which we have found best for rapid healing is a constant 75° with all junipers. The humidity of the sweat box takes care of itself from the reserve within the plunging peat, but the humidity of the entire house when employing the open bench method, requires close attention to be held at not less than 85% relative. Free air temperatures in a normal grafting house may vary considerably without ill effects so long as the humidity is controlled. Serious and irreparable damage to the scion can occur if it is allowed to transpirate too much moisture in a house of low humidity. Perhaps it is not necessary to mention that the amount of water vapor present in a house on a cool morning may be entirely inadequate in that same house when the diurnal temperature fluctuation has raised the free air level on a sunny afternoon. Surely, the best method of insuring against losses owing to this cause is the investment in some sort of humidity control system—I shall not become embroiled in a controversy over which proprietary system is best, but it should at once be simple, reliable, and inexpensive to operate.

The time interval under the conditions described above that is required for a juniper graft to heal adequately, varies considerably with many factors, including variety. There is no hard and fast rule that will dictate a minimum or maximum number of days, save that it should fall somewhere between fifteen and fifty.

When the union of the graft has healed sufficiently, and this can be determined by inspection for abundant callous surrounding the incision and apparent firm attachment of the scion to the understock, the humidity of the holding house can be gradually lowered over a period of one to two weeks, and the bench temperature reduced to approximately 60° by the same time. The graft is now ready for the final step in production; the understock shoot can be cut away above the union and the scion left to grow upon the roots of the understock. The method of this "cutting back" practiced currently at Hill's is to do it all in one cut, for tests conducted here revealed that there was very little, if indeed any, advantage to making this operation in two or three steps. The classic Boskoop method at the time we sought grafting instructions from them, was to trim the shoot of the understock back to the graft union in three separate operations approximately six days apart. While this method provided additional time for the scion to heal more securely to the understock, it did involve just three times the actual hand labor of the method we now use. It is beyond question a shock to the roots of the understock when they find themselves entirely dependent for their food supply on that manufactured by the leaves of the scion, but our overall percentages of success would indicate that this shock is not too great for most to survive when all the small factors have been given adequate attention.

Following this cutting back, the finished grafts can be arranged in either a greenhouse bench or a protected outdoor frame, to await planting early in the spring season. No special care need be given over that normally felt necessary for any greenhouse crop.

It will be noted that no attempt has been made here to go into the many factors which lie between the production of a graft in the greenhouse and the finishing of the juniper in beds, containers, or field rows, for, into this matter, enters the all important matter of scion rooting. This, of course, infers that the entire described process, is only one of "nurse" function, and that when the finished juniper graft is planted to a level below the union for growing on, the scion will strike roots of its own and ultimately become independent of the understock nurse. Professor Chadwick has dealt at length with these aspects in his *Nursery Notes* of January 1951, and for me to repeat them here would be redundant.

Investigation of literature after I was asked to prepare this paper, quickly revealed that there has been very little truly scientific research into the problems of juniper grafting, and that most of the writings are deplorable for their lack of completely definitive descriptions. None of us can learn anything by statements such as "make the graft when the understock is ready," and yet this verbatim sentence was lifted from one of our recognized propagation texts! We all stand to gain much by exercising great care in our writing and being most critical in our reading, for exacting technical subjects, need to be described in accurate, discriminating language, if they are to have any value.

* * * *

MR. HILL: During the past twenty-four hours, I have made several notes about things that have come up in the discussions—obvious points which I have overlooked. I will attempt to deal with them now.

It was evident I made no mention of shade on the greenhouse for grafting. There again, I think that has to be pretty much a rule of experience. Dundee is west of the Great Lakes, therefore, we often get bright sunshine with a great deal of solar radiation, and it has been found to our advantage to have at least light shading most days. In some cases we will put on double or triple covering, to avoid burn of soft understocks of juniper grafts.

The other point which I tried to find out from Mr. Swingle was the time he considered optimum for the removal of the tie from the graft. I haven't gone into that. Our method at Dundee is quite simple. We tie the rubber grafting strip around the stock end with a simple knot—just one tie as you would start to tie your shoes. The tension and flexibility of the rubber keeps that knot in place until we are ready to remove it, at which time either end of the knot can be juggled and the rubber will remove itself from the graft. Our timing on that has not been critical at all. We would like to do it at time of shipping, if we could. As most of you know, we ship grafts in a little different way from most other firms in that we insert a stake in the pot at time of shipping. Before it is taken out of the pot we remove the tie and encircle both the stake and the complete union with two layers of grafting cane and secure the top of the graft to the stake, wrap it from the pot, and ship it that way. It gives a good bit of additional security in the shipping process.

I must confess I don't know when the right time to remove that tie should be. Mr. Swingle indicated there were numerous instances in his experiences where grafts had been inhibited by the tie. He seemed to think that was either the time to replace the tie or at least loosen it.

The other point which I overlooked completely, and it was discussed by Pieter Zorg, was the fact that as we learn more and more about the rooting of cuttings, the need for grafting is evidently going to become less and less. We are continuing to find a number of plants grown from cuttings which we always thought had to be grafted. I noticed several in the list Mr. Zorg read, which he rooted with apparent ease, that we always considered had to be grafted for proper development. That may be due to the fact that with his methods of rooting he gets a plant which grows vigorously.

We discovered in years past that we were able to root a great many plants, however it was not practical to plant on a commercial basis because the subsequent top growth was not vigorous enough to justify it. We fell back to the laborious method of grafting which does produce results I thank you.

* * * *

CHAIRMAN SNYDER: Thank you, Jack, for an interesting account of juniper grafting. I am sure Mr. Hill has made a number of points which will not pass without questions from the floor, so we will now open the discussion for questions.

MR. RICHARD H. FILLMORE (Shenandoah-Lakes Nursery, Shenandoah, Iowa): Have you had any experience with cutting the entire understock off in the beginning, previous to grafting, and then putting on the scion?

MR HILL: I do not believe we have ever cut it back exactly so far as we would consider normal in the regular cutting back process, that is, to the point just immediately above the union. We have experimented somewhat more with stubbing the understock so there was a projection of maybe two inches above the point of union and those two inches contained only a little foliage. I don't think we have tried without leaving some foliage on the understock.

MR. HERBERT TRAUTMAN: In a talk with your cousin, David Hill, he mentioned that he did try cutting off the entire top with very good results. Now, whether that was done before your presence there, I don't remember. It was quite sometime ago.

MR. HILL: Those experiments were one and the same. The stocks were not cut back to the point of union. A stub of two or three inches was left. The results of that work were quite satisfactory. We seemed to think the grafts healed a bit slower, which is always a disadvantage, but in turn it gives more bench space and less suceptibility of *Phomopsis*, which thrives in the sweat box. Phomopsis is almost always carried by the understock rather than the scion.

MR. CHARLES HESS (Hess Nursery, Mountain View, N.J.): In an experimental way we have cut off the understock at the time of grafting with very good results. We have only done a few at a time, and we are a little hesitant about doing it on a full scale.

MR. RICHARD FILLMORE: I think that with a well-established understock and a properly prepared scion, meaning one which has already gone through its normal period of dormancy, that you could probably cut the understock off an inch and a half or so above the top and graft it on the stock with just as good results as with the other procedure. I think that it is something which ought to be gone into much more fully before it is taken into commercial practice however. We are streamlining the grafting process and in a general sense the less fussing one does with grafts, the better they will be.

MR. HILL: It appears to resolve itself into how much stored food is essential for the understock to form the callus requisite for healing. If the understock has enough food stored in the roots and the stem piece to carry out that healing process without delay, then certainly there should be every advantage to it.

PRESIDENT WELLS: I have only been at D. Hill a little over a month, but we have discussed the problems of juniper propagation at some length. They get much better results by pulling two-year old seedlings from seed beds, trimming the roots to an extent that I consider to be drastic, putting the seedlings in pots, and grafting at once, following the procedure outlined by Jack. I have always understood that if you could establish an understock a year ahead that better results are obtained. There might be secondary problems of the understock becoming pot-bound, but that is another problem which is not difficult to solve. I would like to know if anyone else here has had any experience with seedlings which have been potted in the fall or spring, six to twelve months, before grafting.

MR. AART VUYK (Musser Forest, Inc., Indiana, Pa.): Last year I grafted about two thousand junipers in January which had been potted the previous April. It so happened that rabbits had chewed some of the understocks off, consequently we cut the stem off about two inches above the soil. These did just as well as the grafts following the usual procedure.

MR. HILL: That is very interesting. I wonder if Mr. Hess has had any direct comparisons between the grafting of understocks potted in the fall and those potted in the spring.

MR. CHARLES HESS: We raise our junipers from seed, transplant the seedlings to the field in the spring, and then pot them in the fall. Most of the seedlings are used that fall for grafting, however some are kept until the following summer for summer grafting. In other words, we are getting more and more to an all-season production. In the past we only grafted during the winter.

PRESIDENT WELLS: Is there any difference in the percentage of stand between understocks potted in the fall and those established for six to twelve months before grafting?

MR. HESS: No difference that I can see. The stand is just as good.

MR. HILL: At the time of potting these understocks in the fall, did you ever feel it was necessary to cut the roots back more severely than was absolutely necessary for easy potting?

MR. HESS: We trim them back very severely. We have found that when the customer gets the plant in the spring it has a much better root system and it makes a better ball as time goes on.

MR. ZORG: I have grafted junipers on different kinds of two-year old understock. When those plants come out of the beds they have very good roots. They have one big root and many small ones. You have to trim the big root back in order to get it properly potted. I have found that I got losses on the understock before grafting. Consequently I prefer transplanted understock. It takes two years to obtain a two-year transplanted understock.

MR. HILL: Our experience on that has been just exactly the opposite. We have always preferred a seedling understock to a transplanted understock. Perhaps one of the reasons is that we crowd the plants in the beds in order to get a portion of clean, straight stem into which we can graft conveniently. However, with our transplanted stocks, frequently they are not exactly as straight as we would like and also there tends to be foliage rather low on the stock which needs to be trimmed away at the time it is potted. Perhaps for that reason we have used seedling understock directly from the beds.

MR. HOWARD BURTON (Hill Top Nurseries, Casstown, Ohio): Have you ever tried fertilizing the understock in order to stimulate callus formation or have you ever used any root-inducing chemicals applied to the wound?

MR. HILL: No, quite frankly we have not. I can see a wide open field in that direction. However, the potting soil which we use for our understock has always contained quite a generous amount of a complete fertilizer. This year, as I explained, we put in a compost which contained a completely balanced plant food in abundance. Now we could supplement with either liquid fertilizer or perhaps even foliar feeding, but we have not had any experience along these lines. We have not had any experience in the use of hormones to stimulate or improve the healing of the graft union.

MR. FRANK TURNER (Berryhill Nursery Co., Springfield, Ohio): We have had understocks established over a year. They do not perform as well as newly potted stocks. On the matter of the short cut-off, there are a few very old junipers in our area which were cleft grafted. It was done many, many years ago and I don't think there is any way of finding out the rate of success they had.

MR. HILL: The point is that obviously it would work because there are large established plantings produced by that method.

MR. HUGH STEAVENSON (Forrest Keeling Nursery, Elsberry, Mo.): Has anyone had experience with silica sand of the various grades as against ordinary river sand?

DR. CHADWICK (Ohio State University, Columbus, Ohio): We have used silica sand in the rooting of a good many cuttings for several years now. One point in particular that I like about silica sand is the fact that you can get a uniform grade. You can buy it by number and every year it is the same. If you use bank sand, or lake sand, it does vary from year to year.

CHAIRMAN SNYDER: I might add that we have found the same. Bank sand coming from the same firm and obtained from the same pit may vary from one load to another. We, too, use silica sand for much of our work. I would like to point out in connection with rooting of cuttings that you cannot use various media, handled in the same manner, and expect the same results.

MR. HILL: Are there any striking correlations in rooting of cuttings between the obvious acid nature of the silica sand and the tendency to be alkaline on the part of the bank sand we get in the Chicago area?

DR. CHADWICK: The silica sand that we use runs about pH 6.8. Several years ago we found differences in the effect of pH on callus formation, particularly in connection with Andorra juniper. Those tests were run almost thirty years ago. They showed at that time that a pH of about 6.9 to 6.95 was ideal as far as Andorra juniper was concerned. If the pH was on the alkaline side (above 7) a tremendously large callus and very few roots were formed. If the pH was around 4 to 4.5 there was little rooting and no callus formation. We feel that a pH of 6.9 or somewhere in that vicinity is about ideal. I would say as far as our experiments were concerned, the main difference was with Andorra Juniper. We have not seen this difference on Pfitzer's juniper. The pH was lowered by the use of sulfuric acid.

MR. STEAVENSON: With mist propagation, we had a considerable amount of drainage trouble with crematic sand. I wonder if silica sand would overcome that drainage problem?

PRESIDENT WELLS: I would think so. We have run into some similar trouble this summer in the use of mist out in the open. I think that all we have done indicates the necessity for a coarse grade sand through which there is good drainage.

CHAIRMAN SNYDER: Almost without exception, the evidence of both commercial and theoretical propagation indicates that coarse sand is better than fine sand. Aeration and drainage are both involved.

MR. WILLIAM D. COLE (The Cole Nursery Co., Painesville, Ohio): Does anyone know of a suitable injector for adding acid to water for watering purposes? We have water which is alkaline and sometimes causes trouble.

MR. CHARLES HESS: All that is necessary is to put a tank in the house and pump out of the tank. The acid and water are mixed in the tank, the same as with fertilizer.

MR. TEMPLETON: On a long-time commercial basis, in injecting any acidifying agent into the water, the logical apparatus would be the displaced water plant or swimming pool, and the use of aluminum sulphate in the water.

MR. EDWARD H. SCANLON (Cleveland, Ohio): Why couldn't that be done the same as nitrogen is injected into irrigation water in southern California? The nitrogen is contained in a large tank, such as an oxygen tank, put under pressure, and released into the irrigation water.

MR. GABE SIMON (Medina, Ohio): We had a little experience with adding bromine to swimming pool water. There is a device on the market now, manufactured by the Hallogen Supply Company, that costs about $300, with which as little as one part per million can be added to a supply of water.

MR. CHARLES E. HESS (Cornell University, Ithaca, N.Y.): On a recent trip to Ball Seed Company, I saw a device for injecting fertilizer into the water. They watered and fertilized at the same time, however their unit was quite expensive. There is quite a bit of work along this line, particularly in connection with growing established plants under mist. Under continuous mist, there is considerable leaching of the soil, and attempts are being made to incorporate fertilizer, as well as fungicides, etc., into the mist.

MR. HARVEY GRAY (Long Island Agricultural Institute, Farmingdale, New York): In one of our areas at the Agricultural Institute at Farmingdale, we have a series of small Monark nozzles designed to apply mist to ericaceous seedlings. The nozzles give a little over one gallon of water per hour and are set three feet apart. A water pressure of about 200 pounds is used. The water to the mist lines comes from a 30-gallon tank. We have applied both urea and fungicides in the mist simply by adding the material to the water in the tank. The application of nitrogenous material in this manner has been most satisfactory and there has been no evidence of nitrogen deficiency.

CHAIRMAN SNYDER: Thank you, Harvey. Since it is slightly after 12:00 o'clock and this afternoon's panel on magnolias is scheduled to start at 1:15, I think that perhaps we had better adjourn this panel of the propagation of junipers.

President Wells resumed the chair and adjourned the session.

Panel Discussion On Magnolia Propagation

FRIDAY AFTERNOON SESSION

December 11, 1953

The fourth session convened at 1:40 o'clock, President Wells calling the meeting to order.

PRESIDENT WELLS: Gentlemen, the subjects contained in our program were chosen by you. Junipers were first choice and magnolia was second. The selection of magnolias was rather a surprise to some of us. In looking around for someone to moderate this section of the program, it was decided that Professor R. P. Meahl of Pennsylvania State University was the person. He has done a lot of work with woody materials. I think that all of us know his reputation as a top scientist in the nursery industry, and without further ado, therefore, I would like to turn over the meeting to Professor Meahl, who will review the known facts about the propagation of magnolias, and then will moderate the remainder of this session.

CHAIRMAN MEAHL: Thank you, Mr. Wells. As far as the review of literature is concerned, the subject of magnolia propagation is certainly much more scanty, at least as far as I was able to determine, than that which was reported this morning concerning junipers. There is considerable reference to magnolias in this book or that book, in some of the older propagation books and also some of the more recent ones. However these are generalized statements and do not necessarily give any scientific data based on the result of experimentation.

Professor Meahl presented his paper, entitled "Recorded Work on the Propagation of Magnolias—A Review." (Applause)

Recorded Work On The Propagation Of Magnolias—A Review

R. P. MEAHL,
The Pennsylvania State University

A search of the literature reveals very little reference to the propagation of magnolias. Older books on propagation, however, are generally agreed that the seeds exhibit a dormancy, and should be stratified to secure good germination. Before sowing the seed, it was recommended that the outer fleshy covering be removed to prevent rapid deterioration by fungi.

Millais (5) mentioned that *Magnolia macrophylla* seeds sown immediately after gathering, germinated readily. He recommended the storage of freshly gathered seed of *Magnolia grandiflora* in dry sand until February, then in moist sand for seven to ten days to loosen the outer coat. After these coats were removed by washing in water, the seeds should be sown in a cold frame.

Toumey (7) found that seeds of *Magnolia acuminate* gave a germination of only about 3 per cent at maturity, even though about 68 per cent seemed sound. It was his belief that the hard endosperm of these seeds required several months for the absorption of sufficient water for germination.

Evans (4) working with *Magnolia grandiflora* and Afanasiev (1) with *Magnolia acuminata,* reported that the embryo is extremely small (about 1 mm. long and 0.4 mm. in diameter). At the time of maturity, the embryo is fully developed with clearly differentiated hypocotyl and cotyledons. The endosperm is massive and composed of large, thin-walled cells containing the food reserves in the form of proteins and oils It is surrounded by three distinct types of tissue. The outermost, the fleshy pericarp, bright red when mature, consists of three layers of cells, outer epidermis, parenchyma, and inner epidermis. Under the pericarp is a hard dark brown seed coat or testa, which is composed of several rows of cells with thick lignified cell walls. Between the seed coat and the endosperm is the inner membrane or nucellus, consisting of a row of large, elongated cells.

Practically all seeds of *Magnolia* go into a period of dormancy as soon as they reach maturity. The term "dormancy" implies a state of viable seed in which they are unable to germinate when exposed to external conditions that are normally favorable to the germination of the species. Crocker (2) in 1916 listed the following as the chief causes of inability of viable seed to germinate:

(1) necessity for the rudimentary embryo to complete development before germination can take place; (2) inhibition of water absorption by the seed coat; (3) mechanical resistance by enclosing structures to the expansion of the embryo and the seed contents; (4) interference with oxygen intake and perhaps carbon dioxide elimination by the seed coat or by other structures surrounding the embryo; (5) a state of dormancy in the embryo or in some part of it; (6) a combination of the above factors, (7) secondary dormancy.

Evans (4) found that the cause of the delay in germination lay partly, but not entirely, in the lignified seed coat. He conducted tests with seeds of *M. grandiflora* which gave germination in twelve days for seeds with one side of the lignified coat removed but thirty days for those with the lignified coat intact. He also shortened the time of germination by storage of the seed in moist sand at 10°C. for six to ten weeks.

Afanasiev (1) agreed that the seed coat delayed germination, but only to the extent that it slowed down the after-ripening of the embryo. He found that when seeds are after-ripened, germination proceeds similarly in both the naked kernel and the seed with its coat intact, provided neither had been treated with certain chemicals. One of these chemicals is calcium hypochlorite, which was often used to sterilize seed, but which Afanasiev found prevented or delayed germination. He conducted tests which indicated the embryos of non-after-ripened seeds of *M. acuminata* are dormant. Excised embryos and naked kernels of freshly collected seeds failed to grow or germinate. He concluded that although in some cases a small percentage of seeds may germinate immediately upon maturity, the vast majority require a certain period of after-ripening.

After-ripening refers to those physical and chemical changes in a mature viable seed which takes place between the time of seed maturity and germination, and without which the seed is unable to germinate. The exact nature of all the changes taking place during the process of after-ripening is not yet known, although much has been learned. For example, it has been determined that increased acidity and greater water holding capacity accompany the after-ripening of many seed. Also, changes in the activity of two oxidizing enzymes, catalase and peroxidase, have been reported (Eckerson 3). Changes in the amount and form of food reserves have been noted by many workers. These changes ordinarily constitute a gradual transformation of foods from forms unavailable for physiological processes in the seed to easily available forms or to forms easily translocated.

According to Afanasiev (1) the after-ripening of seeds of *M. acuminata* will take place during moist storage at any temperature from 0° to 23°C. However, if stored moist at room temperature for a prolonged period, nearly 100 per cent of the seed would be lost through infection. He secured 86.5 per cent germination with seed stratified at 0°C. as compared to 44.4 per cent with seed stored dry at 0°C. He recommended stratification of approximately eighteen weeks in moist peat moss at a temperature of 5°C. for those seeds intended for spring planting. The peat moss should be kept moist at all times and the pulp should be removed from the seed before stratifying.

Afanasiev also studied the effect of temperature on germination. He used both constant temperatures and temperatures alternating between a low for six hours and a high for eighteen hours. The constant temperatures used were 20°, 25°, 30°, 35°, and 42°C. respectively while the alternating were 5° to 26°, 15° to 26°, and 15° to 30°C. He found that germination at 20° began later and proceeded more slowly than at other temperatures tried. Only 34 per cent had germinated by the end of 30 days, whereas 74 per cent had germinated at 25° and 76 per cent at 30°. Temperatures of 35° reduced germination, with germination ceasing after reaching twelve per cent on the 12th day and all remaining seeds either decayed or began to decay by the end of thirty days. At the temperature of 42°, all seed showed evidence of injury in two days and all were dead in four days. The percentages of germination for the alternating temperatures were 72 for 5° to 26°; 80 for 15° to 26°; and 72 for 15° to 30°.

While conducting his experiments with *M. acuminate* seeds, Afanasiev observed the production of green tissue on the endosperm under certain conditions. Upon further investigation he noted that the pigment seemed to appear only as a result of injury and that it was produced equally as well in the dark as in the light. He also found a close correlation between the ability of seeds to produce the pigment and their viability. Not every seed that produced the pigment germinated but a very high percentage did and every seed that did germinate was also pigmented. Seeds which did not produce the pigment also failed to germinate. He suggested the scratching of the surface of apparently sound kernels and placing them on moist cotton or blotting paper at 24° to 30°C. for several days as a reliable test for germinating ability.

The number of references on propagation by cuttings is even more scant. Some work has been done, however, and reported along with rooting of other plants. Wells (9) has reported some of his work with magnolia. He was successful in rooting *M. soulangeana, M. soulangeana nigra, M. soulangeana Lennei, M. stellata,* and *M. stellata rosea* when taken from early July until late August, wounded at the base, and dipped in hormone powders. He (10) stressed the importance of the age of the stock plants. Cuttings of *M. soulangeana* taken from large plants (20 feet high) had not rooted well over several years, with the percentage of rooting sometimes as low as 40 per cent. In 1952, cuttings taken from young vigorously growing liners, which had been rooted in 1951, gave strong rooting of 99 per cent in five weeks. He (10) also secured excellent results with constant mist in outdoor propagation. The rooting response of *M. soulangeana* was 100 per cent, *M. soulangeana nigra* 92 per cent, *M. stellata* 96 per cent, and *M. stellata rosea* 56 per cent.

Sheat (6) gives general recommendations on grafting but does not report the results of experimental work. He suggests *M. kobus* and *M. grandiflora* as understocks and says that grafting should be done in mid-July to August. The veneer type of grafting is recommended and the cuts should be made as near the base as possible. The union should be completed in thirty days.

LITERATURE CITED

1. AFANASIEV, M. 1937. A physiological study of dormancy in seed of *Magnolia acuminata. Cornell University Agr. Exp. Sta. Memoir.* 208.
2. CROCKER, William. 1916. Mechanics of dormancy in seed. *Amer. Jour. Bot.* 3:99-120.
3. ECKERSON, Sophia. 1913. A physiological and chemical study of after-ripening. *Bot. Gaz.* 55:286-299.
4. EVANS, C. R. 1933. Germination behavior of *Magnolia grandiflora. Bot. Gaz.* 94:729-754.
5. MILLAIS, J. D. 1927. *Magnolia.* Longmans, Green and Co.
6. SHEAT, W. G. 1948. *Propagation of trees, shrubs, and conifers.* Macmillan and Co. London.
7. TOUMEY, J. W. 1916. *Seeding and planting in the practice of forestry.* J. Wiley and Sons.
8. WELLS, J. S. 1949. Magnolias from stem cuttings. *Amer. Nurseryman* 90(10):7-8, 65.

9. ———. 1953. Pointers on propagation: Importance of juvenility. *Amer. Nurseryman* 97(5):14, 87-89.

10. ———. 1953. Outdoor propagation under constant mist. *Amer. Nurseryman* 97(11):14, 51-58.

* * * *

CHAIRMAN MEAHL: I want to thank you for your time and your attention. If there are questions that relate to the reference work, I shall attempt to answer them. If you have questions that relate particularly to the three practical methods of propagating magnolias, however, I suggest that they be held until after the various gentlemen speak on the particular phase of propagation.

MR. RICHARD H. FILLMORE (Shenandoah-Lakes Nursery, Shenandoah, Iowa): What are the environmental conditions which will produce the test type of bleeding-growth on a scratched seed?

CHAIRMAN MEAHL: Afanasiev mentioned that if seed were placed in a moist chamber and kept at room temperature, the green growth or green coloring develops in a relatively short time.

MR. CASE HOOGENDOORN (Hoogendoorn Nursery, Newport, R.I.): Does that just refer to magnolia seed?

CHAIRMAN MEAHL: That I cannot say. His work dealt only with *Magnolia acuminata.* I cannot say if it applies to other kinds of magnolias nor to other types of seed.

MR. HOOGENDOORN: Didn't you also mention a specific reference to a recommendation of *M. acuminata* for understock rather than *M. Kobus*?

CHAIRMAN MEAHL: That was the *Nursery Manual* by Bailey—a general reference on plant propagation. It doesn't say specifically; it just has a paragraph on propagation by grafting. Bailey states that *M. acuminata* is a good understock. I would say there are others that would be better.

MR. HOOGENDOORN: I don't agree with him.

DR. SNYDER (Cornell University, Ithaca, N.Y.): Incidentally, the *Nursery Manual* was last revised in 1921. It was based primarily on the literature and general practices at that time. Although it contains considerable good information, it is very much out of date in many respects.

CHAIRMAN MEAHL: That is the point I wanted to emphasize concerning the literature that is available on the asexual means of propagation of magnolia. What we have is either found in an old book of this sort or it may be a new book, but again, the material in the newer books is frequently based on some earlier traditional work which has been handed down from one propagator to another and is not based on experimental work.

DR. JOHN MAHLSTEDE (Iowa State College, Ames, Iowa): Were you to go through the Woody Plant Seed Manual, which many of you have, you would notice mentioned quite often a temperature of 41 degrees for after-ripening. Even at our institution, we do not have facilities to hold a definite temperature, say within plus or minus two degrees. In reference to magnolia, how important is it to maintain a temperature of 41?

CHAIRMAN MEAHL: I think it can be wide. For many species the temperature can be anywhere from 33 to 50 degrees Fahrenheit. I think if you keep within that range you ought to have satisfactory after-ripening taking place. There might be some seeds which are more specific than this. As far as magnolia is concerned, I feel certain that such a range would be quite satisfactory. The work of Afanasiev indicates it would take place at much higher temperatures, but the difficulty encountered is the destruction of the seed through infection if the temperature is too high, for example around 65 to 70 degrees Fahrenheit.

MR. AART VUYK (Musser Forest, Inc., Indiana, Pa.): I have seen some very good results in grafting magnolias using understock of two-year-old seedlings of *Magnolia liliflora.* They are easy to grow from seed, if the seed are gathered when ripe and planted immediately. It is a very good stock.

MR. SIDNEY WAXMAN (Cornell University, Ithaca, N.Y.): You mentioned the very small size of the embryo. Have you read of any work with excised embryos?

CHAIRMAN MEAHL: Some of these workers to whom I referred did remove the embryo. They were able to get germination if the seed had been after-ripened. If, however, it had not been after-ripened, even though the embryo was removed from the seed, there was no germination.

MR. WAXMAN: Was the medium just plain moisture or a nutrient solution?

CHAIRMAN MEAHL: The report indicated a plain moist medium without nutrients.

DR. SNYDER: Did these reports include any information whether there was any actual change in the size or structure of the embryo from the start of the after-ripening period to the end of it?

CHAIRMAN MEAHL: No, although at the point of germination it had increased about twice the original size from the start of the after-ripening until the seed were ready to germinate. Whether there was a short period when this increase took place or whether it was a gradual increase, I do not know.

MR. HERBERT TRAUTMAN (Trautman Nurseries, Franksville, Wis.): Your statement would lead one to think that possibly the green substance in the seed coat is absorbed in some way by the embryo and makes it possible to germinate afterward.

CHAIRMAN MEAHL: Apparently it had no effect on the germination as such, but if the seed coat was injured slightly this green material developed and it seemed to develop only on those seeds which were viable, that is, with the ability to germinate. Therefore, if the seed is scratched and this green material developed, it was an indication only that the seed was capable of germination. It was not necessary to injure the seed in order to obtain germination. In other words, the green color does not appear unless the seed is injured, but the substance is there. Whether it affects the after-ripening, I do not know.

DR. SNYDER: The fundamental question is "What is after-ripening?" There are quite a number of changes which occur as the embryo becomes after-ripened. Seeds with dormant embryos have different degrees of dormancy. Some dormant embryos will germinate completely if removed from the seed, others will show some degree of activity, such as a slight spreading or greening of the cotyledons, while others will show no evidence of growth unless the embryo has been completely after-ripened. We are concerned with something which has been called after-ripening. Actually this is double talk since we don't know what happens during the period of stratification which makes the seed capable of germinating.

MR. TRAUTMAN: What I meant was that there is a possibility that these chemicals or substances that are necessary are really in the seed coat.

CHAIRMAN MEAHL: I would say there was that possibility, but it has not been determined that the green pigment has any effect on germination. Its presence merely is an indication that the seed is capable of germination when given the right conditions. Let us say when air and moisture get through the seed coat, this green material develops. Whether the same material that makes the green pigment develop is also the same material which will enable the seed to germinate, I don't know.

MR. RICHARD FILLMORE: I am very much interested in obtaining simple tests for viability of the seed of woody plants. It seems to me in the case of these seed which when injured will develop a green color, that there must be a substance there which will permit or encourage germination and which at the same time, or previous to germination, will develop this green coloration so the green coloration and the germination are simply symptomatic of something else which is in there and if we knew what that was, we would have the answer.

CHAIRMAN MEAHL: I think that is right. Gentlemen, we don't want to take any more time from the other speakers. Their material will be much more practical and will be much more helpful to you, I am sure, than that which has been presented up to this point. At this time, I should like to present to you Mr. Fred Galle who will discuss magnolia from seed. Mr. Galle is formerly from the University of Tennessee, later

Ohio State University, and currently at the Ida Casons Garden, Shipley, Georgia.

Mr. Fred Galle presented his paper, entitled "The Propagation of Magnolias by Seed." (Applause)

The Propagation Of Magnolias By Seed

F. C. GALLE
Ida Casons Garden, Shipley, Georgia

Due to my limited experience with only one species (*M. grandiflora*) and only two specific references (1 and 2), I sent out letters to nurserymen and members of the Plant Propagators' Society, requesting their experiences and procedure in handling *Magnolias* by seed. I received twenty-five (25) replies from this inquiry and wish to thank the contributors, for I have compiled my talk from their varied experiences.

From the references and the letters, I obtained information on fifteen (15) species and several varieties. The most common species normally grown from seed were *M. grandiflora, virginiana* (*glauca*), *Kobus, acuminata, soulangeana, and stellata.*

Collecting and handling seed:—The cone-like fruits of magnolia, depending on the species and area, ripen from late summer to fall. The cones consist of several to many coalescent, one to two seeded follicles. At maturity the red to scarlet outer seed coat is fleshy and oily, and the inner seed coat is hard or stony. The seeds when ripe are usually suspended from the open follicle by a slender elastic thread or funiculus. The seed are best collected when the follicles begin to open and are placed in a warm building or greenhouse where they continue to open and expose the seed. Some cones, if collected too immature, will fail to open, making seed removal difficult.

Two nurserymen reported good germination of seed without removing the fleshy outer seed coat, however, all others recommended removal of the fleshy seed coat, taking care not to allow the seed to dry out. The failures and poor germination of imported seed are often due to improper handling and allowing the seed to dry out.

To clean the seed of the fleshy outer seed coat, water is generally recommended. Macerating in hot water is faster than using cold water, however, it was reported by John B. Roller, Verhalen Nursery Company, that with *M. grandiflora,* following the hot water treatment, the seed planted in outside beds would germinate in warm periods during the winter and consequently were frozen. This might be an advantage when planted in a greenhouse. Carl Kern uses a detergent in the final water rinses to remove any oily film or residue. Roger Coggeshall, Arnold Arboretum, uses a Waring Blender to clean seed. The metal blades, however, were replaced with a square piece of truck tire, thus cleaning the seed thoroughly and with no injury to the seed coat.

Ohio State University, and currently at the Ida Casons Garden, Shipley, Georgia.

Mr. Fred Galle presented his paper, entitled "The Propagation of Magnolias by Seed." (Applause)

The Propagation Of Magnolias By Seed

F. C. GALLE
Ida Casons Garden, Shipley, Georgia

Due to my limited experience with only one species (*M. grandiflora*) and only two specific references (1 and 2), I sent out letters to nurserymen and members of the Plant Propagators' Society, requesting their experiences and procedure in handling *Magnolias* by seed. I received twenty-five (25) replies from this inquiry and wish to thank the contributors, for I have compiled my talk from their varied experiences.

From the references and the letters, I obtained information on fifteen (15) species and several varieties. The most common species normally grown from seed were *M. grandiflora, virginiana* (*glauca*), *Kobus, acuminata, soulangeana, and stellata.*

Collecting and handling seed:—The cone-like fruits of magnolia, depending on the species and area, ripen from late summer to fall. The cones consist of several to many coalescent, one to two seeded follicles. At maturity the red to scarlet outer seed coat is fleshy and oily, and the inner seed coat is hard or stony. The seeds when ripe are usually suspended from the open follicle by a slender elastic thread or funiculus. The seed are best collected when the follicles begin to open and are placed in a warm building or greenhouse where they continue to open and expose the seed. Some cones, if collected too immature, will fail to open, making seed removal difficult.

Two nurserymen reported good germination of seed without removing the fleshy outer seed coat, however, all others recommended removal of the fleshy seed coat, taking care not to allow the seed to dry out. The failures and poor germination of imported seed are often due to improper handling and allowing the seed to dry out.

To clean the seed of the fleshy outer seed coat, water is generally recommended. Macerating in hot water is faster than using cold water, however, it was reported by John B. Roller, Verhalen Nursery Company, that with *M. grandiflora,* following the hot water treatment, the seed planted in outside beds would germinate in warm periods during the winter and consequently were frozen. This might be an advantage when planted in a greenhouse. Carl Kern uses a detergent in the final water rinses to remove any oily film or residue. Roger Coggeshall, Arnold Arboretum, uses a Waring Blender to clean seed. The metal blades, however, were replaced with a square piece of truck tire, thus cleaning the seed thoroughly and with no injury to the seed coat.

R. Fillmore, while at the Arnold Arboretum made the following test. Seed of *M. stellata rosea* were collected and divided into lots of fifty (50) each and planted separately in four (4) clay pots. The results are summarized as follows:

Lot No.	Oct. '47	Mar. '48	Germination May, '48	Oct. '48	Germination May, '49
1. (cleaned)	40 degrees	60 degrees	Good	40 degrees	
2. (not cleaned)	40 degrees	60 degrees	None	40 degrees	Fair
3. (cleaned)	60 degrees	60 degrees	None	40 degrees	Poor
4. (not cleaned)	60 degrees	60 degrees	None	40 degrees	Fair

The stated temperatures are approximate. The pots were kept in a cold or warm greenhouse for the indicated period.

Germination:—Handling of seed after cleaning is done several ways depending on facilities available. Clean seed can be planted directly in outdoor beds, cold frames, or under lath. A well-drained soil is desired and a sandy loam and peat moss mixture is generally used. Damping off and rodents are two serious problems. Semesan treatment of seed and sterilized soil will help to control damping off. A leaf mulch is generally used over the seed beds and removed in the spring.

Clean seed can also be sown in flats and placed directly in a cold greenhouse with germination of most species following in the early spring.

Stratification is also commonly practiced. Clean seed is stored in various mediums, such as sand, peat, and a mixture of 50% sand and 50% peat at a temperature of 40 degrees for 60 to 120 days. Coggeshall recommended enclosing seed and medium in a sheet of plastic polyethelene. I have found this method very satisfactory using standard plastic freezing bags. At the end of the stratification period, seed are sown in flats placed in a greenhouse. Hess Nursery plant half of their seed in the fall and stratify half as "crop insurance".

Seedlings as they germinate are pinched off and potted or banded and can be transplanted in the spring to shade or lath bed.

A large number of magnolia seedlings grown are used for grafting stock and seedlings of most species are grafting size in one year. The Washington Arboretum report, however, brought out that some species may be somewhat irregular and unexpected—two species giving a double germination with three years between them, two others germinating twice with a year's interval and still others delaying three years before germination. This brings out the fact that all species do not respond under the same treatment and additional experimental work is necessary. Carl Kern also mentioned that *M. virginiana* (*glauca*) seedlings did not respond to transplanting the first year and should remain undisturbed for one or two years.

Again in closing, I want to thank all the nurserymen who replied to my inquiry and, while I did not mention all their names, I want them to know they had a part in this talk.

LITERATURE CITED

1 MULLIGAN, B. O. AND L. J. MICHUND. 1951. Magnolia Seed Treatment and Germination. *Arboretum Bulletin* (Univ. of Washington, Seattle). Vol. XIV, No. 3

2. *Woody-Plant Seed Manual.* 1948. U.S.D.A. Misc. Pub. No. 654.

MR. LESLIE HANCOCK (Woodland Nurseries, Cooksville, Ontario): Would it be preferable to store the cleaned and sterilized seed in sterile Dutch peat?

MR. GALLE: It very likely would. I have seen the green seed which Professor Meahl mentioned and in connection with this, I am wondering how much of that is algae of some form or another that has not been determined and if, possibly, there is a symbiotic relationship between the seed coat and the green plant growing there.

MR. WILLIAM FLEMER (Princeton Nurseries, Princeton, N.J.): I would like to ask Mr. Carl Kern what kind of plants his seedling magnolias turned out to be in regard to hardiness and kind of flowers?

MR. CARL E. KERN (Wyoming Nurseries, Cincinnati, Ohio): My primary purpose for growing the *M Soulangeana Lennei* seedlings was to produce a suitable understock. Of course, the flowers of all these *Lennei* seedlings vary in size. Some resemble the parent plant.

There is one point, however, I would like to stress. In cleaning magnolia seeds, as you all are aware, the pulp of the seeds contain a large amount of vegetable fats and oils. After the seeds have been de-pulped, the seeds are still coated with a layer of this material and this is a matter of great importance in the germination of the seed. Years ago, to remove the oily layer, I used a lye solution, however, today I have resorted to the common soap detergents. After giving the seeds three or four rinsings in the soapy detergents, we have clean seed.

MR GALLE: I think the variability of seedlings exists in nearly all the predominant varieties, such as *M. grandiflora* and also *M. virginiana* Seedlings vary from types with a narrow-leaf lip to those without the open toe condition to rounded, short, and stuffy leaves. In our area we have 20-year old trees grown from seedlings. Each has a different leaf type. I think the thing that should be emphasized is that someone should collect and select some of the *M. virginiana* seedlings that retain the foliage.

PRESIDENT WELLS: Is there any grower in the room who has raised a good stand of magnolia from seed imported from Japan?

MR. CHARLES HESS (Hess' Nurseries, Mountain View, N.J.): I will answer that in my discussion later.

MR. FLEMER: I would like to ask whether in the opinion of the experts, *Magnolia stellata* is a true species or a selected type. We have raised *M. stellata* seedlings and many of them resemble *M. Kobus* and take a long time to bloom.

MR. GALLE: I think that it is a botanical species. Also there is a very distinct possibility of cross-pollination between these two. Many of the seedlings come into bloom later than *M. stellata,* but probably not as late as *M. Kobus.*

CHAIRMAN MEAHL: Ladies and Gentlemen, because of the time, I think that we should defer further discussion until the open discussion period at the close of this afternoon's panel. At this time we are to have a discussion of magnolia propagation by cuttings. You will notice on the program that Mr. Tom Dodd Jr., of Dodd Nurseries, Inc., Semmes, Alabama, is scheduled to give that report. However, Mr. Dodd is unable to be here. His paper will be read by Mr. Ray Keen, of Kansas State College, Manhattan, Kansas, who is at the present time a graduate student at Ohio State University.

Mr. Ray Keen read Mr. Tom Dodd's paper, entitled "Propagation of Oriental Magnolias from Soft-wood Cuttings." (Applause)

Propagation of Oriental Magnolias from Soft-Wood Cuttings

TOM DODD, JR.
Dodd Nurseries Inc.
Semmes, Alabama

Mr. President, Ladies, and Gentlemen: I am very glad to bring to you this report on MAGNOLIAS FROM CUTTINGS. Dr. Snyder called me last October and asked that I take part in this meeting and I deem it a distinct honor and privilege to do so.

As you probably already know, the Oriental magnolia is a very important crop with the nurserymen in southern Alabama. It is the largest deciduous crop we have and second only to broadleaves in propagation and sales. I would estimate that there are upwards of two and one half million cuttings rooted annually in Mobile County alone. However, in this report, I refer to our own experiences, although our method of propagation is general throughout the county.

The most desirable wood for cuttings is the softest and most succulent wood on the stock plants. To get this type wood, we apply a liberal amount of commercial fertilizer, such as 6-8-4 or 4-10-7, at a rate of about two thousand pounds per acre after the last killing frost which occurs usually before March 15th. Such an application of fertilizer helps to stimulate an earlier growth, thus giving us the desired cutting wood. We

MR. CHARLES HESS (Hess' Nurseries, Mountain View, N.J.): I will answer that in my discussion later.

MR. FLEMER: I would like to ask whether in the opinion of the experts, *Magnolia stellata* is a true species or a selected type. We have raised *M. stellata* seedlings and many of them resemble *M. Kobus* and take a long time to bloom.

MR. GALLE: I think that it is a botanical species. Also there is a very distinct possibility of cross-pollination between these two. Many of the seedlings come into bloom later than *M. stellata,* but probably not as late as *M. Kobus.*

CHAIRMAN MEAHL: Ladies and Gentlemen, because of the time, I think that we should defer further discussion until the open discussion period at the close of this afternoon's panel. At this time we are to have a discussion of magnolia propagation by cuttings. You will notice on the program that Mr. Tom Dodd Jr., of Dodd Nurseries, Inc., Semmes, Alabama, is scheduled to give that report. However, Mr. Dodd is unable to be here. His paper will be read by Mr. Ray Keen, of Kansas State College, Manhattan, Kansas, who is at the present time a graduate student at Ohio State University.

Mr. Ray Keen read Mr. Tom Dodd's paper, entitled "Propagation of Oriental Magnolias from Soft-wood Cuttings." (Applause)

Propagation of Oriental Magnolias from Soft-Wood Cuttings

TOM DODD, JR.
Dodd Nurseries Inc.
Semmes, Alabama

Mr. President, Ladies, and Gentlemen: I am very glad to bring to you this report on MAGNOLIAS FROM CUTTINGS. Dr. Snyder called me last October and asked that I take part in this meeting and I deem it a distinct honor and privilege to do so.

As you probably already know, the Oriental magnolia is a very important crop with the nurserymen in southern Alabama. It is the largest deciduous crop we have and second only to broadleaves in propagation and sales. I would estimate that there are upwards of two and one half million cuttings rooted annually in Mobile County alone. However, in this report, I refer to our own experiences, although our method of propagation is general throughout the county.

The most desirable wood for cuttings is the softest and most succulent wood on the stock plants. To get this type wood, we apply a liberal amount of commercial fertilizer, such as 6-8-4 or 4-10-7, at a rate of about two thousand pounds per acre after the last killing frost which occurs usually before March 15th. Such an application of fertilizer helps to stimulate an earlier growth, thus giving us the desired cutting wood. We sometimes apply the same amount of fertilizer to our lath-house and small field magnolias whenever we feel that a sufficient number of cuttings may not be had from the stock plants.

We begin making cuttings the first or second week of April However, the time sometimes varies, depending on the weather conditions experienced during March.

The length of the cuttings depends largely on the variety, and may be as short as three inches or perhaps as long as ten inches. For instance, *Magnolia stellata,* from three to five inches; *M. Soulangeana,* from four to six inches; and the varieties *Lennei* and *Superba Rosea,* from six to ten inches. All of the varieties are cut at the node, which accounts for the different lengths of the cuttings.

Each cutting is defoliated of all except the two top mature leaves, which are clipped off about half, and the terminal bud is cut out. The cuttings are then placed in a basket and submerged completely in a vat of water containing a prescribed amount of fungicide, usually Othorcide After removal from the fungicide solution and given a sufficient amount of time to properly drain, they are ready for the rooting medium, which in our case, is sand or vermiculite. We use these two separately, but never as a combination. Our experience has shown vermiculite to be far superior to sand on most all varieties except *M. stellata* cuttings, which root just as well in sand.

Immediately before sticking the cuttings into the rows, we treat the butt end of each with Hormodin No. 3 to stimulate an earlier root system.

We thoroughly drench the vermiculite or sand before and after sticking the cuttings. Vermiculite is ready for the cuttings after the first drenching, and under no circumstances, do we use any other method for packing. But to pack the sand we use a specially constructed "T" shaped tamper.

After the cuttings have been placed into the rooting medium, it receives the second and last thorough drenching. However, we syringe the foliage three to five times daily during the five to six week rooting period. The number of syringings depends on the temperature and humidity. We want to maintain the highest temperature possible, but absolutely devoid of any direct sunlight, and the highest possible relative humidity. The temperature outside the greenhouse during this time of the year usually ranges from 85° to 95° Fahrenheit. We have seen the temperature inside the greenhouse go as high as 115° F. during a cloudless day. Not more than thirty minutes is the most any of the men are exposed to this temperature.

Our paramount problem during the rooting process is the control of fungus or "damping-off." Under ideal weather conditions control may be effected by a weekly application of a fungicide. However, if we are plagued with excessive rain and cloudy weather, as is sometimes the case in southern Alabama, the "damping-off" problem is much greater, because fungi really thrive under these conditions. In this case, more applications of the fungicide are required, with, perhaps a little hoping.

We can usually root two crops of Magnolias if we have ideal weather conditions, etc., and can use the same rooting medium for rooting azaleas, *Ilex,* and other broad leaf evergreens.

The preceding is my attempt to give to you in as much detail as possible, our method for propagating Oriental magnolias from soft-wood cuttings. But by no means do I wish to preclude the fact that we still have our biggest problem facing us after the rooting has been effected. This is the task of transplanting the rooted cuttings into the outside beds, and we can experience disappointment if we are not extremely careful, because the winds are usually very hot and dry during May and June.

* * * *

MR. LOUIS VANDERBROOK (Vanderbrook Nurseries, Manchester, Conn.): Tom Dodd mentioned in his article that the men in the greenhouse were subjected to a temperature as high as 115 degrees Fahrenheit for not longer than thirty minutes. I wonder how many of the propagators here have given thought to having their men stick the cuttings at night, as we have done. The cuttings are made during the day, covered with moist burlap until evening, and stuck at night. It takes until about midnight and we give the workers a full day's pay.

MR. HARVEY GRAY (Long Island Agricultural Institute, Farmingdale, N.Y.): This past season it was noticed that with cuttings of *M. Soulangeana* and *M. stellata* carried under mist that there was continued growth if the terminal bud was not removed. With the continued top growth there developed an internal rot in the soft growth. Cuttings without the terminal bud did not develop this condition.

PRESIDENT WELLS: One of the major things that I noticed in our summer propagation was the complete absence of all the normal propagation troubles on all the magnolias that we carried under mist out-of-doors. Now that does not mean to say that we did not have a few cuttings which evidenced the conditions which Mr. Gray mentioned. We did, but they were the few that did not root.

MR. HOOGENDOORN: Do you remove all the terminals from the magnolia cuttings?

PRESIDENT WELLS: No, we use soft cuttings from young plants We like to take cuttings from the one-year liners if we can and under the constant mist you can take those cuttings so soft that they can hardly stand upright. Such cuttings will root with great rapidity and evenness.

MR. HOOGENDOORN: What do you use?

PRESIDENT WELLS: Hormodin No. 3 is too strong on most of that material. We wound all cuttings, use sand without any peat. I know that the Boskoop recommendation is for a mixture of sand and peat, but we have found that peat is definitely harmful.

MR. PIETER G. ZORG (Fairview Evergreen Nurseries, Fairview, Pa.): Since I have been here in the United States I have found that I was wrong. I have lost both *M. liliflora nigra* and *M. Soulangeana* by using about 95% peat. This year, with a 50-50 peat moss and sand mixture and Hormodin No. 2, the cuttings are exceptionally good.

PRESIDENT WELLS: I think I am ahead of you because I didn't have to mix the peat and sand and I didn't have to use peat at all.

MR. PIETER G. ZORG: I don't agree with you.

CHAIRMAN MEAHL: Were your cuttings under mist, Pete?

MR. ZORG: My cuttings were not under mist. They were in the sweat box.

CHAIRMAN MEAHL: If they were under mist I don't think they would have withstood the peat.

MR. ZORG: I don't know.

MR. ROGER COGGESHALL (Arnold Arboretum, Cambridge, Mass): In regard to fungus in the cases where the temperature and humidity are both very high in the summer, we have had a lot of trouble with fungus in mediums of sand and of sand and peat mixture. Where the plastic foam was added to the sand and peat, we didn't have any trouble at all. I understand from the manufacturer that somewhere in the manufacture of the plastic, a bromide is used. Whether that bromide has a definite inhibiting effect on the development of fungus, I don't know.

MR. AART VUYK: I would like to ask Mr. Wells if he has any trouble with wind blowing the mist?

PRESIDENT WELLS: We had no trouble with wind blowing the mist. The fog line was set up in a sash house with the sash removed. The walls of the sash house come up about two or three feet above the surface of the bench. Therefore, there was a small amount of side protection but no top protection of any kind.

MR. HUGH STEAVENSON (Forrest Keeling Nursery, Elsberry, Mo.): This past summer we placed polyethylene panels around our shade house to the height of the nozzles. We had no difficulty with wind blowing the mist away. As a matter of fact, the wind movement probably was beneficial. There was a certain amount of movement of the mist. I believe that the nozzles could be spaced farther apart in a completely enclosed structure. We did have three problems, however. One was that there was not sufficient time to root some of the materials. I think this can be corrected by taking the cuttings earlier. The second problem was lack of adequate drainage in of the beds. There was some bottom rotting on those materials which required a long time to root. The third problem concerned the hardness of the water. Some of the plants actually became white with the deposit of lime.

MR. CARL WILSON (Thompson Products): I can't harmonize three statements that were made here, and while the gentlemen are in the room, I wonder if they would clarify some of the points about fungus infection in relation to the use of mist. This morning, Mr. Zorg talked about spraying juniper cuttings three, four, or five times during the day, but discontinuing the spraying at night so that fungus would not develop. Mr. Templeton has the mist on one minute and off several. Now Mr. Coggeshall from the Arnold Arboretum has discussed a closed case in which the humidity is extremely high.

MR. CHARLES E. HESS (Cornell University, Ithaca, N.Y.): In reply to the question of the relation between high humidity and the use of mist with regard to development of fungus, these are two entirely different situations. Even with a humidity as high as 95 per cent there is a certain amount of water loss from the plants and, if the sunlight is bright, the materials may burn. Under the mist system, however, there is a film of water on the leaf, even when the mist is not on. This film of water has a cooling effect which is not obtained under conditions of high relative humidity. Besides the cooling effect, the film of water markedly reduces the loss of water from the leaf and the plant does not wilt, but constantly remains turgid. The spores of many of the fungi, such as *Botritis*, will not gain entrance into the tissue. Another thing which may help is the possibility that when the fungus spore comes in contact with the leaf it is washed off by the mist.

MR. RAY KEEN: A third factor which should be considered is that the mist is thoroughly saturated with oxygen and there is a possibility that there is enough oxygen there to actually inhibit the growth of the fungus.

MR. CHARLES E. HESS: Another example of the effect of mist on fungus infection can be cited in connection with roses, growing in the greenhouse, which were infected with both mildew and black spot. Two weeks after these plants were placed under mist, the infections had disappeared. Of course, there is a danger that mist might be considered as a "cure-all". Let's not play it up too much and destroy it usefulness. For those of you who have not used mist, I suggest that it be tried out on a limited scale until you are satisfied that it is or is not satisfactory under your conditions.

MR. ROGER PEASE (University of West Virginia, Morgantown, W. Va): There are two points about mist which I would like to bring up. One is that there is a drop in temperature up to 18 degrees inside the frame when mist is used. The temperature reduction is greater with hotter days. The second point, is the suggestion which I made at the meeting last year that possibly we are beginning to over-emphasize the use of mist.

MR. MAURICE H. WILSEY (Wilsey Evergreen Nursery, Corfu, N. Y.): In our propagation, we watch the temperature of the media very closely. I wonder if Mr. Wells or Mr. Templeton can tell me what the temperature of the medium is under their mist conditions?

MR. W. M. TEMPLETON JR. (Winchester, Tenn.): I do not have any idea since we don't measure it.

PRESIDENT WELLS: We do not measure it either.

CHAIRMAN MEAHL: It is time that we continue with the next method of propagating magnolias. If there are further questions, bring them up later in this discussion or save them for the Plant Propagation Question Box tonight. Propagation of magnolias by seeds and by cuttings have been discussed, now it is time to turn our attention to the use of grafting in magnolia propagation. A very experienced gentleman is going to give us the benefit of his experience, Mr. Charles Hess of the Hess' Nurseries, Mountain View, New Jersey.

Mr. Charles Hess presented his paper, entitled "Magnolias from Grafts." (Applause)

Magnolias From Grafts

CHARLES HESS
Hess' Nursery, Mountain View, N.J.

Before going into grafting, I think the first thing to discuss is the growing of the proper understocks. We have found in our experience that *Magnolia Kobus* is the most outstanding understock for all Oriental varieties of magnolias. It is easy to grow and makes a wonderful root system, however, our biggest problem has been to get good seed from the Orient. It is only occasionally that we get seed which has been properly handled. In our experience with *Magnolia Kobus,* once the seed dries out it loses it's germination power. One year we had a bed of seeds from Japan which gave us about a five percent stand the first year, but an excellent stand the second year. It also came up the third, fourth, and fifth year after we planted the seed. I am not able to explain why, but we have found that unless we could get Japanese seed early in the fall and have it packed in damp peat moss, it just will not germinate.

Years ago, we planted our own *M. Kobus* with the idea of growing our own seed. We have, at the present time, about ten specimen plants, which will average thirty feet or more in height and ten to fifteen inches in diameter. Really *Magnolia Kobus* makes a beautiful tree and I am surprised that it is not used more for a medium sized tree in landscape work. It is really a sight worth looking at. Not only are the flowers very beautiful but they have a very distinct odor, something most magnolias do not have. Also it has distinctive fall color of the leaves and the seed pods.

The trouble with growing your own seed of *M. Kobus* is that it blooms very early in the spring, about the same time as *M. Stellata,* and we get a crop only about once in five years. As a rule the flowers get damaged by late spring frost, however, we have bought some Hy-Lo oil-burning salamanders which we are going to use around the magnolia trees when they are in bloom. These salamanders are used extensively in California for protection of the citrus fruit crop. How much success we will have with this I am not certain.

PRESIDENT WELLS: We do not measure it either.

CHAIRMAN MEAHL: It is time that we continue with the next method of propagating magnolias. If there are further questions, bring them up later in this discussion or save them for the Plant Propagation Question Box tonight. Propagation of magnolias by seeds and by cuttings have been discussed, now it is time to turn our attention to the use of grafting in magnolia propagation. A very experienced gentleman is going to give us the benefit of his experience, Mr. Charles Hess of the Hess' Nurseries, Mountain View, New Jersey.

Mr. Charles Hess presented his paper, entitled "Magnolias from Grafts." (Applause)

Magnolias From Grafts

CHARLES HESS

Hess' Nursery, Mountain View, N.J.

Before going into grafting, I think the first thing to discuss is the growing of the proper understocks. We have found in our experience that *Magnolia Kobus* is the most outstanding understock for all Oriental varieties of magnolias. It is easy to grow and makes a wonderful root system, however, our biggest problem has been to get good seed from the Orient. It is only occasionally that we get seed which has been properly handled. In our experience with *Magnolia Kobus,* once the seed dries out it loses it's germination power. One year we had a bed of seeds from Japan which gave us about a five percent stand the first year, but an excellent stand the second year. It also came up the third, fourth, and fifth year after we planted the seed. I am not able to explain why, but we have found that unless we could get Japanese seed early in the fall and have it packed in damp peat moss, it just will not germinate.

Years ago, we planted our own *M. Kobus* with the idea of growing our own seed. We have, at the present time, about ten specimen plants, which will average thirty feet or more in height and ten to fifteen inches in diameter. Really *Magnolia Kobus* makes a beautiful tree and I am surprised that it is not used more for a medium sized tree in landscape work. It is really a sight worth looking at. Not only are the flowers very beautiful but they have a very distinct odor, something most magnolias do not have. Also it has distinctive fall color of the leaves and the seed pods.

The trouble with growing your own seed of *M. Kobus* is that it blooms very early in the spring, about the same time as *M. Stellata,* and we get a crop only about once in five years. As a rule the flowers get damaged by late spring frost, however, we have bought some Hy-Lo oil-burning salamanders which we are going to use around the magnolia trees when they are in bloom. These salamanders are used extensively in California for protection of the citrus fruit crop. How much success we will have with this I am not certain.

Going back to *M. Kobus,* after the seed is ripe we pick the pods just before they start to open and put them in the greenhouse on a bench in the sun. The pods will open in a few days and the seeds will drop out. We extract the seed from the pods and then ferment them in water for about a week or ten days. The pulp of magnolia seed is very oily and it takes a little while to get this pulp off. I will say that the odor is not too agreeable. After this has fermented, the seed is washed, dried, and then immediately stratified or planted. We normally plant about half of our seeds in the fall and stratify the rest to plant in the spring.

This past spring we had three months of rain and we lost ninety percent of our fall sown magnolia seed, however, we were fortunate to have a quantity of stratified seed. These were planted in the spring and gave us a very good stand. We plant the seed in rows in the field from twelve to fifteen inches apart, or in beds six to eight inches apart. We have to be careful not to plant the seed too close because *Magnolia Kobus* grows very fast, and unless they have room, the seedlings will not make grafting size the first year. However if they are planted with plenty of room most of the seedlings will make beautiful stock the first year. Those that do not make size the first year are transplanted in the fall and carried over until the second year. We found one year, when our stand came up too thick, that we could transplant them in the middle of the summer, without any losses. We just took them out, planted them, and never lost one. I did not know that *M. Kobus* was so tough.

We prefer to use *Magnolia acuminata* for grafting the American species of magnolia. We have found that the native magnolias do much better if grown on native stock. *Magnolia cordata,* the yellow cucumber tree, will take on *M. Kobus* but does much better on *M. acuminata.* Of course, if you plant the union underground, the plant will eventually get on its own roots.

In the fall we pot *Magnolia Kobus* before a heavy frost, since we have found that by potting them while the leaves are still on, the plant will re-root in two to three weeks. However, once they become dormant and lose their leaves, it is almost impossible to get them to root until late in the winter. We like to have the understock well established before grafting time.

Another thing to consider is that unless *M. Kobus* is grafted early it will come into leaf in the grafting case, and if it ever does, you are in for trouble. For this reason, we pot them early and we graft them early. We like to graft magnolias in December.

Magnolia acuminata will make a very good understock for the Oriental magnolias, however it possesses a coarse root system. Compared with *M. Kobus, M. acuminata* is difficult to transplant. *M Kobus* comes into growth late in the spring and is excellent for late grafting. One thing we have found about *M. acuminata* is that the only satisfactory way to grow it is in pots for an entire year, thereby getting a good pot-ball before grafting. A satisfactory pot-ball cannot be obtained if they are potted in the fall and grafted the same season.

We have found that it does not make any difference what type of graft is used. As long as the graft is well made, either a side or a veneer graft is satisfactory. We use rubber bands at the present time for grafting magnolias, but in the past we have used waxed string. We found that the string would rot before shipping season and it was necessary to retie them. We do advise the customer to take off the rubber bands because they will not rot if planted below soil level.

In taking off the rubber bands, a little care should be used so that the union does not come loose. With rough handling some of the grafts may break because by the time the graft is planted the scion has made about six inches of new growth and, with the big foliage, the plant is top heavy.

After the grafts are made, they are put in the cases and the cases are kept closed for a week to ten days. The grafts are then given a little air by taking the sash off entirely for an hour or so each morning. The time the sash is off is gradually increased. After the fourth week, we block the sash during the evening, take them off in the morning, and then close them during the day. Eventually we block them day and night. At the end of six weeks the sash is taken off and the grafts are ready to be taken from the case. When we take them out of the case, we cut off the biggest part of the understock, leaving only one leaf to help the understock re-root. Early in March we cut off the balance of the understock and give the plants plenty of room so that they will be ready for shipment in May

We have found that with certain varieties almost one hundred percent of the grafts are successful. With some varieties, however, loss occurs after removal from the grafting case. We have frequently had a 25 to 35 percent loss with *M Lennei.* During the past few years we have had better results with *M. Lennei* using some two year-old wood. We have also waxed the grafts and placed them on an open bench rather than in the grafting case. Although I do not like to use wax, the method has been successful and after all that is what counts.

In closing I would like to say that a great deal of *M Soulangeana nigra* which is being sold is *M. liliflora.* Young plants of *M. liliflora* in our part of New Jersey freeze back year after year. It is an entirely different plant compared with the true *nigra.* Years ago, we obtained some true *nigra* from Holland. It is as hardy as *M. Soulangeana* and we like it because it blooms so much later. The flowers are very seldom, if ever, hurt by late frost.

At the present time we have under trial a *Magnolia Soulangeana* which blooms two weeks or more later than the regular *M. Soulangeana.* It has never been hurt by a late frost. The original specimen plant is located on a private estate. Don't ask me if we have any stock, we only have one plant at the present time. As soon as we know more about it we shall propagate it and put it on the market. If this plant will do as well under cultivation in our nursery as it has on the private estate, I think we have a magnolia of considerable value.

* * * *

MR. JOHN VERMEULEN (Neshanic Station, N.J.): What is the advantage of grafting over cuttings?

MR. HESS: For one thing, I have personal reasons. I have a hobby of fishing in the summer time. I don't want my house full of cuttings in the summer. If I graft, then I can go away after my spring season. Another reason for grafting is that certain varieties do better from grafts.

MR. VERMEULEN: First you have to grow a plant for a whole year before you are ready to start. You are always grafting in the greenhouse just like I have rooted plants in the greenhouse, so you don't gain space. You have the trouble of growing the stock a full year before you are ready to graft. I take cuttings in June or July, and they are ready for sale in the spring. I save a whole year and don't waste any time. I also root *M. Soulangeana Lennei* up to 80 per cent and I think that any time you can get this percent you are doing all right.

MR. HESS: With *Lennei,* we have no trouble getting the grafts to unite but we have had a heavy mortality after they come out of the case. We have found that if you use a side graft there is less loss. Also this year we have used mist and grafted in the open bench. We had practically 100 percent stand with *Lennei* in the open bench. The only thing I object to in waxing is that if there is a hot period in the summer, with temperatures of about 100, the wax will melt and burning will occur. However if they are kept in the shade for a year the wax will have peeled off. But the important thing is that when you use wax keep them in the shade.

MR. JACK SIEBENTHALER (The Siebenthaler Company, Dayton, Ohio): Mr. Hess, I would like a discussion on the use of the intermediate method of injecting a shield for your late blooming *M. Soulangeana.*

MR. HESS: I am very interested in this. That is one of the things that comes out of meetings such as this one. I think what this Society ought to do is have a medal made and give it once a year to a man who has done something outstanding. Mr. Nicolin certainly should have one because this technique is really something new.

MR. RICHARD FILLMORE: Well, I think he should have a medal because so far as I know it would be the second genuinely new budding technique in about 1,000 years. The original budding method was probably worked out 1,000 or more years ago and it was perhaps fifty or sixty years ago that the patch budding method was developed for propagating nut trees on the Pacific Coast. I would like to have someone who knows more about budding than I do go through the literature and see if this is genuinely true.

MR. HOOGENDOORN: Mr. Hess, do you bury the graft union?

MR. HESS: Not in magnolias. In certain types of grafting we do bury the union. The reason we did bury the unions years ago when we first started grafting was that we waxed the union. Now we don't wax. We found that the main thing which has given us trouble was damping off.

When we give more air by keeping our cases blocked in the daytime, we have much less damping off and do not have to wax the unions. It has been a great help in biotas and certain junipers.

MR. HOOGENDOORN: Did you say that you grafted *Lenneis* on an open bench?

MR. HESS: Yes, with perfect success.

MR. HOOGENDOORN: Without waxing them?

MR. HESS: We used to cut the scions and wax them before grafting. Now we graft them and dip the plant. However the wax at the bottom of the container is considerably hotter than at the top and the top of the scion may be burned. This doesn't show up immediately. It is necessary to be fairly careful that the wax is not too hot. It is necessary to use a wax that melts at a low temperature.

PRESIDENT WELLS. I would like to add a couple of comments to this discussion. We have used open bench grafting quite successfully on a wide variety of plants. We wax everything that is dormant and has no leaves. We cut off the dogwood understock, graft on the stump, dip into the wax, and set on the open bench. The same is true with maples. On conifers, such as biotas, *Cedrus atlantica glauca,* and *Cryptomeria,* we do not wax but bury in peat in the open bench. All were equally successful. The only requirement is a constant, even temperature in the bench so that callus formation is constant and rapid

Coming to just one other comment on the over-wintering of magnolia cuttings, we come back, inevitably, to constant mist. If the cuttings are taken early enough, they can be potted early enough in the summer to get them well established in the pots and to secure new growth. This is the important factor. Then they will come through the winter without any trouble in an ordinary frame which is adequately protected against violent fluctuations of temperature.

MR. HESS: As I mentioned in my paper, five years ago we got a quantity of seeds of *Magnolia Kobus* from Japan which was shipped in the usual dry way. We planted the seed and got about five percent germination. As we dumped those seedlings out in the fall, we happened to examine the seed and found that they were still alive So we recovered the bed. The next spring we had about eighty percent stand. That was the second year. It continued to germinate for five years. I wonder if Professor Meahl will explain what happened to the seed?

CHAIRMAN MEAHL: It must have gone into a very long secondary dormancy. It has been reported that these seed will go into a secondary dormancy, however, that was an extremely long one.

MR. RICHARD FILLMORE: I can't explain it, but I was told quite a few years ago that if you wanted to be sure to get all the magnolia seedlings possible from a group of seed that the seeds should be sown in the same bed every year.

MR. HESS: With our own seed we normally get a few coming up the second year, but I never had it come up five years later.

MR. FRED GALLE: In a report in the arboretum bulletin from the University of Washington, the same thing is mentioned. Seed from two specimens germinated the second year, and in another case seed germinated over a three-year period.

MR. LESLIE HANCOCK: Mr. Chairman, at the risk of being a diversionary, may I say that I am surprised that we haven't discussed the layering of magnolia. I know very little about magnolia propagation, in fact, nothing at all. I thought that I would find out about it when I visited in Boskoop in 1948. There I saw long, leafless shoots of magnolia bent over to the ground and layered. I thought that looked very wonderful but probably costly. At home, I had six or seven large specimens of *Magnolia Soulangeana nigra* which had produced a lot of young shoots from the base and were unsalable for plantings. I thought to myself why not just lay those shoots along the ground. I prepared some wires and wired them down to the ground. There was a very solid row of one year or two year shoots along the ground. I did that in the early spring and thought I would leave them there until the young shoots started to grow. Gradually, as they grew, I piled soil around them and at the end of one year there were a few roots. I left them one more year, and from those six or seven plants, I took nearly 1,000 rooted layers. Every single shoot that grew up that had been properly handled produced a plant. Now this being so, it all seems rather curious to me why we have gone to such lengths to produce magnolias by grafting and cuttings.

MR. HESS: If you want mass production you have to use either grafting or cuttings. Another layering method—mounding—is used in Chase, Alabama. To produce ten or twenty thousand magnolias by layering it would be necessary to have a whale of a lot of stock plants. If you want mass production as was mentioned for the Mobile area—two and a half million cuttings a year—layering is too slow a process.

MR. FLEMER: I would like to comment further on open bench grafting. By knowing that we are going to abandon the waxing in the grafting of magnolia, beech, and red maples, we simply cut off the stock and graft with a long slender union onto the scion, set the pots closely on the bench, and cover with four inches of peat. We get wonderful results.

MR. HESS: We don't put our maples in a case. We don't even wax them, and we have done away with glass.

MR. FLEMER: It cuts down on the fungus.

MR. HESS: If we were to use in our propagation the grafting methods of forty years ago, we would have a 100 percent loss. It doesn't work. In Boskoop today, they can't do what they did forty years ago. For example, they have trouble in grafting hemlocks. Why, I don't know.

CHAIRMAN MEAHL: If there are no further questions nor comments, I will turn the meeting back to President Wells.

PRESIDENT WELLS: Thank you, Professor Meahl, and thank you very much Fred Galle, Tom Dodd, and Charlie Hess. I would just like to say that the meeting this evening will start promptly at 8:00 p.m. I can see there is going to be a lot of discussion this evening so we want to start on time.

The session recessed at 4:00 o'clock.

* * * *

PLANT PROPAGATION QUESTION BOX

Friday Evening, December 11, 1953

The Question Box session proved to be quite an interesting meeting. More than thirty-five questions, submitted prior to the session, were discussed. This was followed by a series of very interesting slides. It was decided, however, to omit the transcription of this session because of the length of the proceedings.

* * * *

Panel on Hardwood Cuttings

SATURDAY MORNING

December 12, 1953

The session convened at 9:40 o'clock, President Wells calling the meeting to order.

PRESIDENT JAMES S. WELLS (D. Hill Nursery, Dundee, Illinois): One of the subjects which a lot of people felt should have been covered last year was the propagation of deciduous shrubs in all of its phases. This year, we have included the propagation of deciduous shrubs by hardwood and softwood cuttings and we have purposely kept this subject until the last day so that we could have a full and vigorous day. Without further ado, therefore, I will turn the meeting over to Dr. L. C. Chadwick, of the Department of Horticulture, Ohio State University, who will moderate the panel this morning and discuss "The Fundamentals of Propagating Deciduous Shrubs by Hardwood Cuttings."

DR. CHADWICK took the chair and presented his paper. (Applause)

The Fundamentals of Propagating Deciduous Shrubs By Hardwood Cuttings

DR. L. C. CHADWICK
Department of Horticulture, Ohio State University

Hardwood cuttings have been used as a means of propagating deciduous shrubs and trees for centuries. It is an economical and efficient method of production and it is surprising that so little attention, experimentally, has been given to the practice. A survey of the literature indicates relatively few research publications dealing with this method of propagation.

In commercial practice this method of propagation has been confined largely to types of plants that root easily from cuttings. Other than with fruits, little attempt has been made on the part of research workers, to formulate procedures whereby this method could be used with cuttings of some of the more difficult-to-root plants. The method is worthy of further exploitation.

Commercial, hardwood cuttings of deciduous shrubs are handled in two different ways. The most common method is to make long cuttings during the winter months, tieing them in bundles and storing them in a cool place over winter. These cuttings are lined out directly in the field in the spring. Modifications of this method are to plant out the cuttings directly when made thus avoiding the storage period, and handling the cuttings in open frames or beds rather than in the open field.

The second method consists of making short hardwood cuttings which are rooted in sand or other mediums in a cool greenhouse during the winter months. My discussion will deal primarily with practices followed in connection with the former method, since practically no experiment work has been done with the short hardwood cuttings. Some of the fundamentals discussed, however, will apply to both groups.

IMPORTANT FACTORS INVOLVED IN THE ROOTINGS OF CUTTINGS

The important factors in the rooting of cuttings may be classified as either (1) internal or (2) external. One group of factors is no more important than the other and successful propagation depends upon a careful manipulation of all of the factors.

Internal Factors—In general, the important internal factors can be classified as being either of an anatomical or physiological nature. The main anatomical factors concern the proper healing of the wound made by the cut or cuts and the presence or ability to form root initials.

Priestley and Swingle (20) indicate in their monumental work on the anatomical aspects of vegetative propagation that the first step in the successful rooting of cuttings was the quick healing of the wound and that the healing process took place in three steps: (1) suberin formation, (2) the development of internal cork and (3) callus formation.

Suberin is formed by the oxidation of fatty substances in the cutting and may be deposited on the superficial cell layers of the cut within 1 to 48 hours after the cutting is made. To be effective in protecting the cutting against microorganisms, healing must be rapid. Such is the case with suberin provided there is a free access of oxygen and rapid drying out of the cut ends of the cutting does not occur.

At its best, suberin is only a temporary protective layer. Fortunately, an internal cork is formed rather rapidly, by the division of cells in the region of the vascular cambium. These cells which form parallel to the cut surface, are similar to phellogen or cork cambium cells, and form the first, and probably in many cases, the most important, permanent wound healing tissue.

The last of the wound tissues to form is the callus. While it is indicative of favorable conditions within the cutting for rooting, its formation is not necessary for rooting and if the callus is excessive, may even retard rooting. Its formation is so slow that it affords little protection to the cutting.

While some experimental work has been done on its nature, and the factors influencing the formation of callus on softwood cuttings, there has been little research from these standpoints on hardwood cuttings. Early investigators, such as Stoll (26), pointed out that callus could be formed from every tissue of the stem excepting the true wood and epidermis. More recently, Priestley and Swingle (20) and Sledge (24) have shown that the most common source of the callus is the cambium, tissues closely aligned to cambium, or the phellogen.

Van der Lek (31) pointed out that if the buds were removed from the cutting callusing would be poor. No attempt was made to correlate this statement with the common practice of de-eyeing some cuttings and its effect on callusing and rooting. Coinciding with the statement by Van der Lek is the report by Swingle (28) that callusing is most active in the spring after the rest in the buds is broken. This statement is in agreement with common observation.

Shippy (22) reported that callusing can be hastened or retarded by regulating the temperature. He reported that callusing would form within a temperature range of 40° to 90°F. but that 60° to 70°F. was the most favorable temperature range. He further reported that callusing would take place under conditions of less oxygen than does rooting.

Knight (15) working primarily with apple cuttings, reported that callusing was favored by high moisture content of the soil. Callusing of cuttings stuck in sandy soil could be greatly increased by artificial watering. It was indicated that under some circumstances, it might be feasible to callus cuttings in clay soil before placing them in sandy soil to root.

The second important anatomical factor underlying the successful rooting of cuttings is the presence or ability to form root initials. There is little in the literature pertaining to this factor as it applies to the rooting of hardwood cuttings. Swingle (27) pointed out that the presence of burr-knots on apple cuttings increased their rooting ability. While we know that adventitious roots may arise from almost all tissues of the stem, it is probably true as Priestley and Swingle (20) suggest, that with cuttings of mature wood, adventitious roots most often arise in the neighborhood of the cambium, that their origin is closely associated with the ray cells and that more than one type of cell is involved in their development.

Concerning the physiological factors important to the successful rooting of cuttings, I would like to confine my remarks to (1) food supply, (2) auxins, and (3) rest.

An ample supply of food has always been considered as an important factor in the rooting of cuttings. This factor is particularly important with deciduous hardwood cuttings since the development of roots is dependent upon the food stored in the cuttings. As an indication of the importance of food supply to rooting, a few references may be quoted.

I. Bayley Balfour (1) reported that he considered the two most essential factors in the rooting of cuttings to be (1) adequate supply of food materials and (2) an abundance of moisture. Winkler (33) reported that the rooting percentage of grape cuttings could be closely predicted by determining the amount of starch in the cuttings. The greater the quantity of starch the greater the rooting percentage and the viability of the rooted cuttings.

Carlson (3) in her studies to determine the reasons for the variation in the rooting of overwintered canes of Dorothy Perkins and American Pillar roses, reported that the variation was dependent upon the quantity of reserve starch in the canes. Dorothy Perkins canes showed more reserve starch and rooted readily. The author further points out that the starch content in the canes of American Pillar rose reached a maximum in December and then began to decrease, whereas the maximum starch content in the canes of the Dorothy Perkins rose was not reached until January or February. This report emphasizes the fact that we need more study of the translocation of foods in stems of our ornamental plants. With this information we could better time the best period for taking cuttings.

Several investigators have shown that the rooting percentage of cuttings could be increased by soaking the cuttings for certain periods in sugar solutions. Most of these reports have dealt with softwood cuttings, but Chadwick (5) reported that the percent of rooting and the quality of the root systems of European Privet, *Ligustrum vulgare*, could be increased by this practice. He did not recommend it as a general commercial practice, however.

The presence of auxin, or true plant hormone, is probably as essential to the successful rooting of hardwood cuttings as with softwoods but there is little information in the literature indicating the importance of this factor. Several investigators, including Van der Lek (31), have associated the extent of activity within the buds of hardwood cuttings with the presence of a hormone and correlated it with the rapidity of callusing and rooting.

The degree of rest in buds greatly influences the speed of callusing and rooting, and the methods by which hardwood cuttings can be handled successfully. Since this factor is so closely correlated with the time of taking cuttings and the method of storage or handling, its discussion will be delayed for later consideration under cultural factors.

External Factors—For the purpose of this discussion I propose to group the external factors into two categories namely, (1) environmental and (2) cultural. As will be seen by the discussion there is considerable overlapping of the factors within the two groups.

The most important environmental factors that I wish to discuss are water, oxygen, temperature and light.

Water—In consideration of the water factor attention should be given to the moisture of the storage medium, moisture of the rooting medium and moisture in the air about the cuttings The literature indicates no comparative experimental tests regarding the moisture content of the storage medium. It is usually considered that a medium should be used that will maintain a fairly high and uniform moisture content. It is important that fluctuations be avoided. Peat, sawdust, and combinations of these with sand are satisfactory. The storage medium selected may well depend on the conditions under which the cuttings are stored. Chadwick (4) has reported equal results using sand, a mixture of equal parts of sand and peat and peat moss It is best to keep the peat just moist and limit its use to short periods of storage.

When handling short hardwood cuttings in the greenhouse during the winter or early spring months, the rooting medium may be carried slightly drier than for leafy cuttings. Cuttings stuck in field rows, as is the common practice, will be benefitted by a soil which has good aeration. Knight (15) and Knight and Witt (16) have indicated that rooting is favored by a soil moisture content somewhat lower than that most satisfactory for callusing.

Day (7) reported that slicing, slitting and scraping of the basal ends of the cuttings of California Privet, Quince and Muscat Grape increased water absorption 2 to 3 times and thereby rooting was increased.

No experimental data are available indicating the regulation of humidity with hardwood cuttings. It, of course, is not as an exacting a factor with hardwoods as with softwood cuttings but the presence of a fairly high humidity is advisable in greenhouses where short hardwood cuttings are handled.

Oxygen—The oxygen requirements for favorable rooting of hardwood cuttings varies with different plants. This point was brought out by Zimmerman (35) working with long stem pieces of *Prunus domestica, Rhodotypos, Weigela, Lonicera, Philadelphus, Salix and Ribes.* A well drained, sandy soil should supply ample oxygen for successful rooting.

Temperature—As hardwood cuttings are usually handled in the field, there is little or no control over temperature. Some experimental work had been done, however, on determining the most favorable temperatures for rooting and storage of such cuttings.

Zimmerman (34) working with cuttings of *Ilex verticillata* and other plants reported that the temperature of the rooting medium had little effect on types that were difficult to root but the higher the temperature, within reason, the quicker the rooting with easy-to-root types.

Swingle (28) experimenting with factors effecting the callusing and rooting of apple cuttings reported that the optimum temperature for rooting (75-85°F.) was shifted or modified according to the oxygen and moisture content of the rooting medium and the maturity of the shoot from which the cuttings were taken. Under conditions of low oxygen and high moisture, the optimum temperature was lower. The optimum temperature was higher for cuttings taken in the fall than for those taken in the spring. Attention should be given to these conclusions in handling short hardwood cuttings in the greenhouse.

Chadwick (4) reported an experiment indicating the importance of temperature regulation for stored cuttings which is summarized in the table given below.

Such storage treatments have been repeated several times with many types of hardwood cuttings. In the majority of the tests, if the cuttings were taken in the late fall or early winter before rest in the buds was broken, best results were obtained when they were stored for approximately two weeks at 60°-65°F. and then for the remainder of the period at 40°F. A continuous storage temperature of 40°F. was more satisfactory for cuttings taken in mid to late winter after the rest in the buds was broken.

The explanation of the favorable results under the conditions of variable storage temperatures for cuttings taken early, is based on the fact that the two week storage period at 60°-65°F. results in good wound healing and callusing and starts root initial development. The following

Table I. Factors Influencing the Rooting of Hardwood Cuttings. Cuttings Taken in November. Those stored were lined out in April.

Plant	Percentage rooting when: Taken and lined out No storage	Stored continuously at 40°F.	Stored 2 weeks at 60-65°F. then at 40°F.	Stored at 40° except last 2 wks. at 60-65°F.	Taken in April and lined out No storage
Cornus alba	20	60	80	48	72
Hibiscus syriacus	20	64	56	28	8
Ligustrum vulgare	88	—	—	—	100
Lonicera morrowi	84	36	76	20	84

40°F. temperature breaks the rest in the buds but holds shoot growth to a minimum. Root initials may continue to develop slowly in this temperature but seldom to the extent of protrusion. Under such conditions, when the cuttings are lined out in early spring, both roots and shoots are ready to develop simultaneously, a favorable condition. The variable storage temperature is readily accomplished commercially by storing cuttings in boxes which can be moved from a warm greenhouse (60°-65°F.) to a cold storage building where temperatures ranging from 32° to 40°F.'

Light—Light is not a factor to be considered in the rooting of hardwood cuttings as usually handled in storage and the open field. It might be pointed out, however, that Zimmerman (34) reported that hardwood cuttings of *Ilex verticillata* would root as readily in the dark as in the light. Commercial propagators have often experienced the rooting of hardwood cuttings in storage if the temperature was not kept fairly low.

There is some evidence that etiolation may be used as a practice to increase rooting of some difficult to root hardwood cuttings.

Vyvyan (32) working with hardwood cuttings of plums reported that the etiolation of the base of shoots of common Mussel plum improved rooting of basal cuttings but depressed rooting in cuttings taken higher on the shoots. However, Sinka and Vyvyan (23) reported later that etiolation of the basal end of shoots of Pershore plum rootstock did not retard rooting of the middle and top cuttings. Also along this same line, Van Cauwenberghe (30) working with plum rootstocks reported that winter cuttings from etiolated shoots from layered beds rooted 77 per cent, much better than non-etiolated cuttings.

The above reports show the possibilities of increasing rooting of difficult-to-root cuttings by etiolation. This practice is not beyond the limits of commercial adaptation and further experimental work might be conducted to determine its limitations. How etiolation brings about increased rooting is speculative. It may depend simply upon the softening of the stem tissues, it may be tied up with an accumulation of carbohydrates or hormones at the etiolated stem portion or it may be due to the fact that an endodermal tissue is formed at the etiolated point. Priestley and Swingle (20) have pointed out a correlation between the presence of this tissue and the ease of rooting.

Among the most important of the cultural factors are such practices as (1) type of cutting taken, (2) time of taking, (3) rooting medium (greenhouse cuttings), (4) watering methods, (5) position of the cuts and mechanical equipment used in making cuttings, (6) chemical treatments, (7) bud removal, (8) fertilization of cuttings and (9) pest control. Some of these factors need little discussion from a scientific point of view and no research data were found concerning them.

Type of cutting—There is ample proof that careful selection of the cutting wood is important. The following few references will bear out this point. Calma and Richey (2) suggested that the center cuttings from shoots of Concord grapes should be used if best rooting was to be obtained. This statement was based on the carbohydrate-nitrogen relationship in the shoots. Carbohydrates were found to be highest in the center portion of the shoot, lowest at the tip and intermediate at the base. This fact has also been pointed out by other investigators.

Tukey and Brase (29) investigating means of rooting cuttings of fruit trees reported that cuttings of Malling I and IX apple stocks taken from layered plants in March and stuck in the field would root nearly 60% if a heel of two-year wood was included. They also reported that heel cuttings of quince were better than those made from one-year wood.

Vyvyan (32) and his associates (23) reported that Myrobalan B plum cuttings taken from a hedge, rooted better than those from one-year plants or from layered bed plants. Rooting varied from 28 percent for cuttings from a mature hedge.

While there seems to be little experimental work to prove the practice, most hardwood cuttings of ornamental shrubs are made 6 to 10 inches long of the past season's growth. In this connection Hoffman (11) reported that the best cuttings of *Salix alba* were those 6 to 8 inches long, 10-15 mm. thick, from the middle of one-year twigs. Contradictory to the practice of taking this length of cutting is the report of Van Cauwenberghe (30) that 14-inch cuttings of plum rootstock are better than those 8 to 9 inches long.

Time of taking and method of storage—There is relatively little experimental data to support many of the practices followed regarding the time of taking on the storing of hardwood cuttings. However, certain of these practices are followed rather religiously in commercial circles. As an example, hardwood cuttings of Virginal Mockorange are often taken previous to the time of hard freezes and planted out after danger of hard late spring frosts have passed. Taking cuttings early of those plants that are on the border line for hardiness is, of course, a desirable practice.

Johnston (12) reported that with blueberry cuttings of varieties susceptible to winter injury that they should be taken early and stored in a cool, moist place Cuttings of varieties not subject to winter injury are best taken in late March or just before growth starts and put directly in frames for rooting.

Schwartze and Myhre (21) reported that with blueberry cuttings to be rooted without bottom heat, that they should be taken after March 1, set at once in a propagating bed or stored in a cool place and covered with damp peat until the last of March. If bottom heat is to be used in rooting, take the cuttings from February 22 to late March either for storage or immediate use. Bottom heat at 70°F. greatly improved the rooting of hardwood cuttings. Van Cauwenberghe (30) suggested in his report on quince A pear rootstock, that cuttings taken at leaf fall gave almost no rooting even when treated with synthetic growth substances. Cuttings taken in March with a heel gave 87% rooting compared with 39 percent without a heel.

These reports, as well as observations, would seem to indicate that the old practice of taking hardwood cuttings in the late fall, after a few hard freezes, cutting them into lengths of 6 to 10 inches, and storing them in bundles of 25-50 until spring has been or can be altered considerably. Hardwood cuttings of many shrubs can be taken at almost anytime during the winter months and good results expected if they are handled correctly.

To lend support to this statement Chadwick (4) took cuttings of three common shrubs each month from November to April inclusive and reported (table 2) good rooting over much of this period. Cuttings taken after January 1, rooted with a higher percentage than those taken earlier.

Table 2. The Influence of the time of taking on the Rooting of Hardwood Cuttings.*

Plant	Percentage rooting when taken in					
	Nov.	Dec.	Jan.	Feb.	March	April
Cornus alba	62	64	76	78	66	68
Ligustrum vugare	0	8	86	70	98	100
Lonicera morrowi	48	54	76	92	98	68

*All cuttings stored in a mixture of damp peat moss and sand until lined out in April, except those taken in April which were field planted directly

It might be mentioned here that there appears to be no scientific basis for storing cuttings out-of-doors with their bases up and tops down as frequently practiced. It has been inferred that this method of storage favors callusing and restricts top growth because of the variation in temperature at the different ends of the cuttings. Better control of temperature can be had by storing cuttings in boxes and holding them in a storage building. Horizontal storage of the bundles of cuttings under such conditions is as satisfactory as storing them on end.

Rooting medium—Few reports have appeared in the literature concerning this factor. Investigations have been limited primarily to the handling of short hardwood cuttings in the greenhouse and confined largely to handling blueberry cuttings.

Stene and Christopher (25) working with hardwood cuttings of blueberry recommended that granulated peat moss be used as the rooting medium. The addition of sand with the peat was of no advantage. In contrast to this report Schwartze and Myrhe (21) reported that Canadian peat and clean sand in the ratio of 3:1 was the best rooting medium for blueberry cuttings. Also O'Rourke (17) reported that the most satisfactory way of handling hardwood cuttings of the Atrococcium variety of blueberry was to take cuttings 4 inches long, of one-year uniform wood, in the last half of March and hold them in moist peat in cold storage until April 5th when they should be stuck in a cold frame containing 5 inches of a medium consisting of ⅓ peat and ⅔ sand.

Doran (10) reported that a rooting medium of 2 parts sand and 1 part peat moss was a satisfactory rooting medium for hardwood cuttings of *Franklinia* and *Magnolia virginiana.*

These reports show little, if any, consistence in respect to the "best" rooting medium. The main conclusion that can be derived is that the best rooting medium will vary with the type of plant being propagated and the conditions under which the cuttings are handled.

Position of the cuts and Mechanical Equipment Used in Preparation of the Cuttings—Until recent years hardwood cuttings were made individually with some uniformity in respect to the position of the terminal and basal buds in relation to the cuts. Never, however, has this practice been as exacting as that followed with softwood cuttings. Today, hardwood cuttings are made with the aid of hatchets, band saws and other types of cutters, with nothing uniform about the cuttings except the length. The failure of cuttings to grow where a terminal side bud is missing is more than offset by the economy envolved. However, a few reports in the literature indicate the importance of the position of the terminal or basal bud in respect to the cut.

Chadwick (4) reporting on his work with hardwood cuttings of *Cornus alba, Ligustrum vulgare* and *Lonicera morrowi* indicated that varying the basal cut from one-half inch below the node to just below the node was of no consequence but suggested that a good, strong bud near the terminal end of the cutting was advisable.

Hoffman (11) reported that with hardwood cuttings of *Salix Alba* that the basal cut should be made as straight across as possible and that the cuttings should have a single main bud, with no side buds, near the upper end. Where there are several closely spaced main buds or with several side buds, a leaning or crooked trunk is produced.

Sinka and Vyvyan (23) made top cuts on Myrobalan B plum cuttings just above and just below a bud. They reported that varying the terminal cut was of no significance. O'Rourke (18) working with blueberry cuttings recommended that in order to save wood and labor. that cuttings not be recut; that the top cut on one cutting become the basal cut on the next cutting where several are made from the same shoot. The long internode piece below the lower bud was not detrimental except with the variety June.

It seems apparent that varietal differences may well influence the practices followed.

Bud Removal—Disbudding of some hardwood cuttings is a common commercial practice. Little attention has been given to the effect of the presence of buds on rooting. A few observations that have been made indicate that the presence of buds on hardwood cuttings, even though in a state of rest when taken, will influence the speed of rooting and perhaps the quality of the root system. It is definitely true that some activity in the buds soon after the cuttings are taken will speed rooting. The results will be unfavorable, however, if shoot growth occurs much ahead of root development. In this connection, Van der Lek (31) reported that the removal of buds previous to their breaking inhibited rooting but Sledge (24) inferred that disbudding only slowed the rooting process.

O'Rourke (17) conducted some experiments in an attempt to determine the effect of the presence of flower buds on the rooting of hardwood cuttings of blueberry. The average percentage of rooting of cuttings with only vegetative buds present was about 40 percent while cuttings bearing both vegetative and flower buds rooted less than 5 percent. The author states, however, that it is not the presence of the flower buds that makes the difference but it is the condition in the wood that favors the set of flower buds that retards rooting.

Chemical treatments—Early reports by Curtis (6), Chadwick (5) and Klein (14) showed that the treatment of cuttings of *Ligustrum ovalifolium, Ligustrum vulgare* and other plants with solutions of potassium permanganate would not only increase the percentage of rooting but also the quality of the roots. With the advent of the synthetic growth substances, the use of potassium permanganate and other oxidizing compounds for root stimulation passed almost completely from use. Many of the basic references on growth regulators early pointed out that for such materials to be effective, leaves or a growing tip should be present, consequently they were reported as being relatively ineffective in increasing the rooting of hardwood cuttings of deciduous plants. More recent investigations, however, seem to indicate that they may be effective under some conditions. Only a few references will be given here to show the controversial nature of the reports.

Pearse (19) treated the basal ends of dormant willow cuttings with lanolin paste and water solutions containing indolbutyric acid and reported that the treatment greatly stimulated the formation of roots. Removal of the treated portion eliminated the effect but a further treatment again caused the response. Treating the apical ends of cuttings accelerated root formation throughout the length of the cuttings.

Johnson (13) in checking the influence of certain synthetic growth substances on the rooting of hardwood cuttings reported that Hormodin A and Auxilin were of no value in stimulating the rooting of the varieties

Adams, Cabot, Primier and Rubel. Schwartze and Myhre (21) also reported that root inducing substances were of no value in stimulating the rooting of blueberry cuttings.

Sinka and Vyvyan (23) treated common Mussel and Pershore plum rootstocks with 20 ppm indolebutyric acid before planting. The treatment greatly increased the rooting of basal and middle cuttings from etiolated shoots of each variety. Tip cuttings were not effected. The authors further report that treating cuttings of Myrobalan B and Pershore plum rootstocks and of Malling II and IX with indolebutyric acid or its potassium salt had no effect.

Van Cauwenberghe (30) reported that the treating of cuttings of plum rootstocks with Stimroot (A-Naphthyleneacetic acid and B-indolebutyric acid) and dichlorophenoxyacetic acid made little difference in the rooting response. On the other hand Dirkshit (9) indicated in his report that indolebutyric acid was effective in rooting of cuttings of the plum varieties Early Round, Howe and Kelsey. Denja (8) was successful in rooting hardwood cuttings of mulberry when treated with 0.01 percent heteroauxin.

Recently there have been reports that the combination of growth regulators and a fungicide might be more effective than either material alone in stimulating the rooting of cuttings. One of the most striking reports of the value of such a treatment is the one recently made by Doran (10) in which he used a combination of Phygon XL and indolebutyric acid. With cuttings of *Franklinia alatamaha* taken on October 10, no rooting was obtained with check cuttings, 50 percent rooting where indolebutyric acid was used and 78.6% where both Phygon XL and indolebutyric acid were used in combination. Cuttings of *Magnolia virginiana* taken on January 28, showed equally phenomenal results, as shown in Table III.

Table III. Effect of Various Treatments on the Rooting of Hardwood Cuttings of *Magnolia virginiana.*

Treatment	*Percentage Rooted*
Check—no treatment	0.0
Phygon XL—In talc 1:2	40.1
Indolebutyric Acid—60 mg/L/24 hrs.	51.8
Indolebutyric Acid—60 mg/L/24 hrs. followed by Phygon XL in talc 1.2	81.6

Such results certainly warrant further tests.

Little information is available from a scientific standpoint on watering, fertilization or pest control as management practices in connection with hardwood cuttings. Their importance, however, is realized by commercial propagators.

In conclusion, an attempt has been made to review the literature as it applies to the fundamental practices involved in the making, storage and rooting of hardwood shrub cuttings. The literature is contradictory in many respects but the fundamental basis for many of the practices followed in the rooting of hardwood cuttings is shown.

Actually, only limited attention has been given this method of propagation by scientific investigators. Perhaps with more research it would be found that hardwood cuttings could be used much more extensively as a means of propagation, even to the extent of using the method with cuttings of some of the more difficult-to-root plants.

REFERENCES CITED

1. BALFOUR, I. Bayley. 1913. Some problems in propagation. *Jour. Royal Hort. Soc.* 38: 447-461.
2. CALMA, V. C., & H. W. RICHEY. 1931. Growth of Concord grape cuttings in relation to vigor, chemical composition and relative position on the cane. *Proc. Amer. Soc Hort. Sci.* 28: 131-137.
3. CARLSON, Margery C. 1929. Microchemical studies of rooting and non-rooting rose cuttings. *Bot. Gaz.* 87: 64-81.
4. CHADWICK, L. C. 1931. Factors influencing the rooting of deciduous hardwood cuttings. *Proc. Amer. Soc. Hort. Sci.* 28: 455-459.
5. CHADWICK, L. C. 1933. Studies in Plant Propagation. *New York Agr. Exp. Sta. Bul.* 571. 1-53 (Cornell)
6. CURTIS, O. F. 1918. Stimulation of root growth in cuttings by treatment with chemical compounds Cornell Univ. Agr. Exp. Sta. *Memoir* 14: 71-138.
7. DAY, Leonard H 1932. Is the increased rooting of wounded cuttings sometime due to water absorption. *Proc. Amer. Soc. Hort. Sci.* 29: 350-352.
8. DENZA, M. I. Rooting Mulberry hardwood cuttings. Doklady vsesojuz. *Akad. Seljsk.* (Russian)
9. DIRKSHIT, N. N. 1953 Propagation of three varieties of Prunus species by stem cuttings. *Current Science* 22: 47-48.
10. DORAN, Wm. L. 1952. Effects of treating cuttings of woody plants with both root inducing substances and a fungicide. *Proc. Amer. Soc. Hort. Sci.* 60. 487-491.
11. HOFFMAN, Rudlof. 1938. Die vermehrung der baumweide (*Salix alba*). *Forstwiss. Central* 61: 41-52, 86-101.
12. JOHNSTON, Stanley. 1930 The propagation of the highbush blueberry. *Michigan State College Bul* 202.
13. JOHNSTON, Stanley. 1939 The influence of certain hormone-like substances on rooting of hardwood blueberry cuttings. *Michigan State College Bul.* 21: 255-258.
14. KLEIN, Irwin. 1930. Stimulative action of chemicals on the rooting of softwood and hardwood cuttings. *Proc. Amer. Soc. Hort. Sci.* 27: 482-486.

15. KNIGHT, R. C. 1926. The propagation of fruit tree stocks by stem cuttings. 1. Observations on the factors governing the rooting of hardwood cuttings. *Jour Pomology & Hort. Sci.* 5: 248-266.

16. KNIGHT, R. C. & A. W. WITT. 1927. The propagation of fruit tree stock by stem cuttings. II. Trials with hard and softwood cuttings. *Jour. Pom. & Hort. Sci.* 6: 47-60.

17. O'ROURKE, F. L. 1942. The influence of blossom buds on rooting of hardwood cuttings of blueberry. *Proc. Amer. Soc. Hort. Sci.* 40: 332-334.

18. O'ROURKE, F. L. 1952. The influence of the position of the basal cut on rooting of hardwood cuttings of blueberry. *Proc. Amer. Soc. Hort. Sci.* 59: 153-154.

19. PEARSE, H. L. 1938. Experiments with growth-controlling substances. 1. The reaction of leafless woody cuttings to treatment with root-forming substances. *Ann. Botany* (London) 2: 227-235.

20. PRIESTLEY, J. H. & Chas. F. SWINGLE. 1929. Vegetative propagation from the standpoint of plant anatomy. *U.S.D.A. Tech. Bul.* 151: 1-100.

21. SCHWARTZE, C. D. & Arthur S. MYHRE. 1952. Propagation of Blueberries. *State College of Washington Bul.* 488: 1-32.

22. SHIPPY, Wm. B. 1930. Influence of environment on the callusing of apple cuttings and grafts. *Amer. Jour. Bot.* 17: 290-327.

23. SINKA, A. C. & M. C. VYVYAN. 1943. Studies on the vegetative propagation of fruit tree rootstocks. II. By hardwood cuttings. *Jour. Pomology* and *Hort. Sci.* 20: 127-135.

24. SLEDGE, W. A. 1930. The rooting of woody cuttings considered from the standpoint of anatomy. *Jour. Pom. & Hort. Sci.* 8: 1-23.

25. STENE, A. E. & E. P. CHRISTOPHER. 1941. Some problems affecting the rooting of hardwood blueberry cuttings. *Proc. Amer. Soc. Hort. Sci.* 39: 259-261.

26. STOLL, R. 1874. Uber die bilding des kallus bei stecklingen. *Bot. Zeit. 22:* 737-742, 753-768, 785-798.

27. SWINGLE, C. F. 1925. The use of burr-knots in the vegetative propagation of apple varieties. *Proc. Amer. Soc. Hort. Sci.* 22: 228-230.

28. SWINGLE, C. F. 1929. A physiological study of rooting and callusing in apple and willow. *Jour. Agr. Res. 39:* 81-128.

29. TUKEY, H. B. & Karl BRASE. 1931. Experience in rooting soft and and hardwood cuttings of hardy fruits. *Proc. Amer. Soc. Hort. Sci.* 28. 460-464.

30. VAN CAUWENBERGHE, E. 1950. Vermenigvuldiging vangeidentificeerde pruimenonderstammen door stekken Rigkstuinbouwschoal Vilvorde. (Belgium) 31 pages.

31. VAN DER LEK, H. A. A. 1925. *Root development in wood cuttings.* H. Veennan & Zonen. Wageningen.

32. VYVYAN, M. C. 1942. The propagation of fruit tree stock by stem cuttings. III. Further observations on hardwood cuttings. *Ann. Rept. East Malling Res. Stat. A26:* 40-47.

33. WINKLER, A. J. 1927. Some factors influencing the rooting of vine cuttings. *Hilgardia 2:* 329-349.

34. ZIMMERMAN, P. W. 1925. Vegetative plant propagation with special reference to cuttings. *Proc. Amer. Soc. Hort. Sci. 22:* 223-228.

35. ZIMMERMAN, P. W. 1930. Oxygen requirement for root growth of cuttings in water. *Amer. Jour. Bot. 17:* 842-861.

* * * *

CHAIRMAN CHADWICK: I am going to ask that you hold questions until we have had the practical slant on this matter of handling hardwood cuttings. Without further delay, I want to call on Louis Vanderbrook for his discussion of handling of hardwood cuttings.

MR. LOUIS VANDERBROOK (Manchester, Conn.) presented his paper, entitled "Hardwood Cuttings of Deciduous Shrubs." (Applause)

Hardwood Cuttings of Deciduous Shrubs

LOUIS C. VANDERBROOK
Vanderbrook Nurseries—Manchester, Conn.

In the propagation of deciduous shrubs from hardwood cuttings one of the first things we have to consider is that we are dealing with living organisms, and care must be taken in all our procedures to prevent death or losses. It therefore becomes necessary that we carefully select our cutting wood from healthy plants and only when it is in a ripened or good condition. In our nursery we have established stock blocks of most all the varieties which we propagate and in time will have every variety included in the stock blocks.

We usually cut our wood in the late fall after we have had sufficient frost to thoroughly ripen the wood. It is then brought into the warehouse and kept in a moist, cold part of the building until we are ready to start making the cuttings.

Cuttings which are going to be planted in the field outdoors in the spring are made up in eight inch lengths, starting about February 1st after we have finished our other winter work, tied in bundles of approximately 100 and then placed butts downward in boxes deep enough to accommodate the entire length of the cuttings. We use either moist peat moss or other packing material on the bottoms and around the bundles of cuttings.

The boxes of cuttings are then stored in the cold part of the ware-

31. VAN DER LEK, H. A. A. 1925. *Root development in wood cuttings.* H. Veennan & Zonen. Wageningen.

32. VYVYAN, M. C. 1942. The propagation of fruit tree stock by stem cuttings. III. Further observations on hardwood cuttings. *Ann. Rept. East Malling Res. Stat. A26:* 40-47.

33. WINKLER, A. J. 1927. Some factors influencing the rooting of vine cuttings. *Hilgardia 2:* 329-349.

34. ZIMMERMAN, P. W. 1925. Vegetative plant propagation with special reference to cuttings. *Proc. Amer. Soc. Hort. Sci. 22:* 223-228.

35. ZIMMERMAN, P. W. 1930. Oxygen requirement for root growth of cuttings in water. *Amer. Jour. Bot. 17:* 842-861.

* * * *

CHAIRMAN CHADWICK: I am going to ask that you hold questions until we have had the practical slant on this matter of handling hardwood cuttings. Without further delay, I want to call on Louis Vanderbrook for his discussion of handling of hardwood cuttings.

MR. LOUIS VANDERBROOK (Manchester, Conn.) presented his paper, entitled "Hardwood Cuttings of Deciduous Shrubs." (Applause)

Hardwood Cuttings of Deciduous Shrubs

Louis C. Vanderbrook

Vanderbrook Nurseries—Manchester, Conn.

In the propagation of deciduous shrubs from hardwood cuttings one of the first things we have to consider is that we are dealing with living organisms, and care must be taken in all our procedures to prevent death or losses. It therefore becomes necessary that we carefully select our cutting wood from healthy plants and only when it is in a ripened or good condition. In our nursery we have established stock blocks of most all the varieties which we propagate and in time will have every variety included in the stock blocks.

We usually cut our wood in the late fall after we have had sufficient frost to thoroughly ripen the wood. It is then brought into the warehouse and kept in a moist, cold part of the building until we are ready to start making the cuttings.

Cuttings which are going to be planted in the field outdoors in the spring are made up in eight inch lengths, starting about February 1st after we have finished our other winter work, tied in bundles of approximately 100 and then placed butts downward in boxes deep enough to accommodate the entire length of the cuttings. We use either moist peat moss or other packing material on the bottoms and around the bundles of cuttings.

The boxes of cuttings are then stored in the cold part of the warehouse, placed one upon the top of the other with 2 x 4 inch blocks between the boxes to allow some air circulation and light. In the spring, when the land is ready for planting, we take the boxes of cuttings, just as they were packed during the winter, out to the field and plant directly from the boxes.

The varieties which we grow in this manner include *Forsythia, Spiraea, Cornus, Symphoricarpus, Lonicera, Ligustrum, Deutzia, Philadelphus, Weigelia* and the general run of varieties which root easily outdoors.

This procedure or method which I have outlined most nurserymen are conversant with, and use for reproducing deciduous shrubs.

About twenty-five years ago we decided to experiment with hardwood cuttings in the greenhouse during the winter months to see if the production of certain hardwood deciduous varieties, which did not root too well planted outdoors, could be increased or improved upon.

One of these varieties was Amur River Privet, which planted outdoors in the spring, did not always produce sufficient percentages of plants to satisfy us. When we grew these in the greenhouse, the results were very satisfactory, netting practically 100% after several angles of propagating had been solved.

The wood for this greenhouse growing is cut at the same time and in the same manner as our other hardwoods. But when it is in the warehouse, we store this wood tied in bundles, but set the bundles with their butts or bottoms on the moist dirt floor until ready to make them up.

The next step is to fit and prepare the greenhouses. For this type of growing we have used by the low propagating houses and the higher forcing or growing houses, and either type works equally well.

The benches are built so that they will hold at least eight inches of sharp, clean sand of the concrete grade. This is leveled off with a board so the bench is full to the top, and then the sand is lightly watered and pounded down firm, using a building brick. After pounding, the sand is again watered lightly and is ready for planting or dibbling.

We have started the winter propagating of these cuttings February 1st and even March 1st after completing our other winter work, and they have done equally well regardless of time started. If it were possible, we would even make and plant them in January, but we are usually not through with the other work of trimming, planting stock, etc.

These cuttings are made different than the field grown type, which is eight inches. The greenhouse cuttings we make only about 3½ inches long, as this is sufficient length, and we thereby get double the amount of new plants from the wood as we do by the other method.

Now we come to a critical step in the procedure. As these cuttings have been stored in a cold moist warehouse and with possibly some old dead foliage on the wood which frost did not entirely remove during the fall, or the wood may have been exposed to old moss spores or fungi which may be present in the warehouse, we take these 3½" cuttings after they have been made up, place them in a coarse screen and wash them with cold water under the strongest force of pressure which we can get with a hose to wash them clean of all possible fungi.

They are then laid in flats inside a wet piece of burlap and placed in the cold warehouse while waiting for the dibblers in the greenhouse to plant them in the sand. The dibblers take the flats of cuttings into the greenhouse, keeping them covered with the wet burlap until planting them.

The cuttings are planted in a trench, made with a trowel which has been flattened out with a hammer, and all but the top one-half inch of the cutting is shoved down in the sand.

As each row of cuttings are planted, they are pounded down tight with a piece of 2 x 2 inch hard lumber, the pounding being done with hammers. The next row is then marked off two inches from the last with the trowel and the process repeated until all benches are filled.

The fresh planted cuttings are flooded down with a coarse nozzle until all sand is washed level. From then on the cuttings are not watered for at least one week. The greenhouse vents are kept closed and a temperature of 55 degrees Fahrenheit or better is maintained. As soon as the cuttings leaf out, they are watered lightly and the vents are opened to air the house and plants during the daytime. During cold weather all vents are closed at night to prevent too sharp a temperature drop.

At this stage the propagator has to use extreme care not to water too much, or mold or fungi will start damping off the foliage and the crop will be ruined.

Also, if the weather is clear and there is bright sunshine, the glass must be shaded by using either lime, kemtone or some other method of shading. We use a Paragon pressure sprayer and spray our glass with hot lime as needed for shade. True, snow storms will accumulate on the glass and as the snow melts and slides off the greenhouse, some lime will come off the glass also, but with the spray method of application it does not take long to shade the glass as desired.

About three weeks from the time the cuttings were planted they will begin to form callus and start to root. At this time the ventilation should be increased to about 50% of total, and the watering can be stepped up slightly, however it is still very necessary to watch for damping off.

The most difficult time to control the cuttings and prevent mold or damping off is during the month of March, when practically the entire month may be cloudy weather with very high humidity and not much breeze to give air circulation.

While propagating this type of crop, the greenhouses and cuttings should be checked twice daily to prevent anything getting out of control.

By the middle of April most all varieties will be well rooted and maximum ventilation should be put on and watering cut down or watched very carefully. Temperatures are kept at 55 degrees Fahrenheit at least at all times during the growing of the crop, until planted.

In New England we never plant these soft topped cuttings until after Decoration Day and all danger of freezing temperatures has passed. When ready to plant, the cuttings are lifted from the greenhouse benches and placed upright in boxes with the roots in moist sand. The boxes transported out to the fields and the cuttings are planted immediately. The ground is well firmed.

This year we sprayed all cuttings in the greenhouse before lifting from the benches with Wiltpruf to prevent any wilting or sun scald, when planted out. This spray paid off in less loss after planting from sun scald or hot weather, and we shall continue this practice in the future.

Now a few words about hormones or root inducing powders on the hardwood cuttings in the greenhouse. We have experimented with many types and strengths and have found that the use of such powders will severely burn and rot the bottoms of the cuttings and very seriously reduce the number of plants callusing and rooting.

This does not mean that we have stopped experimenting, as we run experiments of all kinds all the time. Some of them cost us money, others save us money, but we continually learn something new every year.

Some varieties of shrubs which will not root by this method are: *Forsythia suspensa, Rhodotypus kerroides, Weigelia, Spiraea van houttei,* Hybrid Lilac, *Spiraea prunifolia,* and *Kolkwitzia amabilis.* We have tried all these many times but they do not root enough to pay commercially, so these varieties we root in the summer from soft wood cuttings, pot them up in September and carry them over the winter in cold frames under sash covered with reed mats to prevent alternate freezing and thawing, which would cause heaving out of the pots.

Some of the varieties which we do root successfully from hardwoods in the greenhouse include Almond Pink, Almond White, *Philadelphus virginalis, Kerria japonica, Spiraea Anthony Waterer, Ligustrum amurense, Ligustrum obtusifolium regelianum, Syringa persica,* and *Symphoricarpos racemosus.*

Whenever our production on other varieties drops, due to losses from drought or other causes, we also put these short supply items in the greenhouse because, as mentioned before, with a cutting only 3½ inches long we get twice the yield from the same amount of cutting wood as would be obtained by rooting from eight inch cuttings in the field planting in the spring.

We have tried other rooting mediums than sand, including vermiculite and several others, but have rejected them all in favor of clean sand, as we find we have less trouble with rot or damping off with sand than any other medium. Vermiculite and many other mediums hold too much water too long and cause too much rot. Also, they cannot be firmed as tightly as sand. One thing I have tried on these cuttings and found to be beneficial at times is sulphur dust. I tried sulphur dust on some of the cuttings and found that it made a difference of 50 per cent in the stand.

Someone may ask why do we require benches deep enough to hold eight inches of sand when we use only a 3-½ inch cutting. The answer is we like plenty of medium below our cuttings to induce good rooting. Also, in the summer we use the same greenhouses and the same sand for the second crop to root our soft wood cuttings, which are made longer than the hardwood type. Our softwood cuttings are made six inches or longer, depending upon the varieties and the type of wood, whether it is long or close jointed between leaves.

We clean out the sand in all our greenhouses once each year—in the fall after removing all softwood propagation—and refill with new clean sand. Thus we get two crops per year from each greenhouse and still have some time for repairs, painting and general upkeep.

* * * *

CHAIRMAN CHADWICK: Thank you, Louie, for that very fine and concise report.

MR. JOHN B. ROLLER (Verhalen Nursery Co., Scottsville, Texas): I would like to ask Mr. Vanderbrook if he has ever tried using hormones on the base of the cuttings and then storing the cuttings with the butts up, packed in some material like moist sawdust?

MR. VANDERBROOK: No, we have never done that. I have put the hormones on them, stored then horizontally, and in such materials as sphagnum, peat moss, sawdust, and shavings. None of the methods in which we have ever used hormones gave us anything but negative results. I have never tried storing them upside down.

MR. ROLLER: With *Wisteria*, which is one of the main hardwood cuttings we make, we incorporate the hormones in the regular clay mud, as we do all our cuttings, put it on the base of the cuttings, and store them with the butts up and covered with wet sawdust. If we don't get them in the ground in about six weeks, part of them are already rooted.

MR. VANDERBROOK: One other observation I would like to make is that years ago the thought used to be that all hardwood cuttings had to be stored so they would be callused and rooted when they went out in the field. We don't want our hardwood cuttings rooted before we plant them in the field.

MR. ROBERT J. FRANTZ (Niles, Michigan): I didn't quite understand the application of sulphur.

MR. VANDERBROOK: The sulphur dust is used exactly the same as any hormone powder. Take moist cuttings, shake off the surplus moisture, and plunge the base of the cutting into the sulphur in the same manner as treating with a hormone.

DR. L. BAUMGARTNER (Baumlanda Horticultural Research Laboratory, Croton Falls, N.Y.): I would like to comment on the sulphur treatment from the point of view of safety. I am always concerned when I think of people using some of these things that are rather dangerous, such as sulphuric acid. Sulphuric acid for the control of the pH of the rooting medium can be extremely serious material if an accident happens, and it is possible to use this same procedure that was mentioned for treating cuttings for the control of the pH of the rooting medium because sulphur in the presence of water will form sulphuric acid, but it does so at a slow rate. It is safe to handle and is not too difficult on the plants. I believe it would be a lot better from the stand point of safety of the workmen if you dispensed with the use of concentrated or even dilute sulphuric acid and used sulphur instead.

MR. CARL KERN (Wyoming Nurseries, Cincinnati, Ohio): I just heard a remark made about the storing of hardwood cuttings in an upside down position. I want to report this practice was first advocated in the early 1800's by Steven Albrecht, of Zurich, Switzerland. I have also seen this practice used in France and Germany. We prefer to store our cuttings out of doors in trenches. We store our cuttings upside down. The cut ends are near the surface. That again relates itself to matters of temperature and air. We find we get a much better callusing action. At the same time it will retard the bud growth because the buds are down where it is cooler. It has always been my practice to retard the bud growth as much as possible and encourage callusing as quickly as possible.

In regard to the early bud-breaking varieties, such as *Lonicera fragrantissima*, we make the cuttings and plant them in open field rows as soon as possible. In storing cuttings in boxes filled with peat moss or sawdust, often a large number of cuttings are lost, especially those with thin bark. You get rot in the boxes where there is an exclusion of air. I may remind you of the tremendous number of cuttings we have made. We have made millions of cuttings of Paradise apple and of multiflora rose. The success in rooting these cuttings by handling them in an upside down position is a very, very advantageous procedure.

CHAIRMAN CHADWICK: Carl has proposed a question and answered it himself. I am familiar, of course, with the old practice of storing cuttings upside down and outside Personally, our thinking in this matter is exactly the same. We are after the same end and we are after good management and the proper regulation of temperature, oxygen, and moisture. I still feel that we can do a better job under controlled conditions inside than can be done outside.

MR. VANDERBROOK: I would like to mention that, with the possible exception of California privet, the way we store cuttings in boxes we don't have any rot or fungus.

MR. KERN: Do you have trouble with *Weigelia*?

MR. VANDERBROOK: No we do not.

MR. JACK SIEBENTHALER (The Siebenthaler Co., Dayton 5, Ohio): My question concerns the planting of hardwood cuttings in the fall. If they are stuck in the ground, what is the best method of preventing heaving?

CHAIRMAN CHADWICK: We follow the practice of making the cuttings from eight to ten inches long They are set in a well drained sandy soil, planted deep so that only an inch or so of the cutting is above the surface. Under these conditions we do not have any trouble of heaving. I think there might be some trouble in heavier soils, however. Has anyone had any experience of putting the cuttings out in the fall and mulching to prevent heaving?

MR. RICHARD FILLMORE (Shenandoah Nurseries, Shenandoah, Iowa): It is a common practice in the Shenandoah Nurseries to leave the top exposed for an inch or so and to ridge the rows of cuttings. In the spring, the ridge is pulled away with rakes. Whether it is a real good cultural practice or not, I don't know, but they have been doing it for a long time.

MR. KERN: I might say that is a similar procedure to what we follow. Sometimes we use a ridge of sawdust. Ordinarily we just cover them with soil. We have very little trouble with heaving.

CHAIRMAN CHADWICK. I think that there are a lot of other questions which might be asked, however it is essential that we close this panel so that the business meeting may be held. Thank you very much for your interest and participation.

Panel on Propagation By Softwood Cuttings

SATURDAY AFTERNOON SESSION

December 12, 1953

The session convened at 2:00 p.m., President Wells presiding.

President Wells asked that all members of committees meet immediately at the close of the program in order to discuss membership applications and the future plan of operation for the Field Trials Committee.

PRESIDENT WELLS: This afternoon session is a continuation of the morning program, and features the propagation of deciduous shrubs by means of softwood cuttings.

The moderator of this program is Dr. John Mahlstede, of Iowa State College, Ames, Iowa. I must own that I am entirely ignorant of Dr. Mahlstede. I know nothing about him whatsoever, but his comments of the past few days and the cut of his jib is enough for me, and that is why I asked him to serve on this Committee of Field Testing. I feel quite sure that he will be able to assist us very materially in the running of this program which we adopted this morning. Without further comment, therefore, I would like to hand the meeting over to Dr. Mahlstede.

Dr. John P. Mahlstede took the chair.

CHAIRMAN MAHLSTEDE: Thank you, President Wells, ladies and gentlemen: As I see by our time schedule it is necessary that we progress fairly rapidly in order to adequately cover that phase of propagation which is concerned with the rooting of softwood cuttings of deciduous shrubs.

Dr. Mahlstede presented his paper on "Principles of Rooting Softwood Cuttings of Deciduous Shrubs." (Applause)

Principles of Rooting Softwood Cuttings of Deciduous Shrubs[1]

J. P. Mahlstede
Department of Horticulture, Iowa State College

A knowledge of the various physiological and anatomical conditions which exist at the time of collection and which are concerned with the process of root development, in any cutting type will, in time, result not only in increased stands, but also in the more efficient operation of the propagation end of the nursery business.

This presentation has been divided into two parts; one, which discusses the literature which may be applied to softwood cuttings in gen-

[1]Journal Paper No. *J-2457* of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 1214.

eral, and another which summarizes this material as it is related to softwood propagation under constant mist. Each of these topics, in turn is divided into a number of sections which present the appropriate data in a logical sequence, progressing from the selection of propagating wood, through cutting preparation and rooting.

Internal Factors Governing Successful Rooting of Softwood Cuttings

Introduction

Under ideal growing conditions, the ability of a cutting to produce adventitious roots depends on the physiological and anatomical conditions that exist in the shoot. All of the various factors, which are incorporated under these two headings should be taken into consideration in the selection and preparation of the wood for propagation.

Selection of propagating wood

In selecting material for softwood cuttings, the physiological conditions of food supply and of hormone balance are of prime importance.

Food Supply

It is a well known fact that softwood cuttings, sampled at midseason from stock plants growing under poor soil fertility conditions will root slower than cuttings sampled from plants growing under good soil management practices. Preston and his co-workers (18) have found that succulent tip cuttings of azaleas selected from plants receiving a low level of nitrogen gave better rooting than cuttings taken from plants receiving a high level. This brings us to the controversial question of the carbohydrate-nitrogen relationship as it effects root production in cuttings.

Stored food is not an important factor when selecting softwood cutting material early in the season. It is apparent that by early sampling, tissues of softwood cuttings have little stored food reserve, and consequently the soluble food used in the formation of roots must come as a result of the photosynthetic activity of the cutting in the propagating bed.

In selecting softwood cutting material later in the season, it is the commercial practice to take thin wood, produced laterally on shoots, rather than vigorous leaders. It has been generally accepted that a high carbohydrate-nitrogen ratio favors root production. In this connection, Starring (20) has noted that when carbohydrates were lacking or were very low in the cutting, roots were not initiated. Brandon (2), working with the genus *Rosa,* suggests that in general, June is the most effective month for sampling softwoods of this genus, and that starch accumulation by the shoot appeared to have no relation to the ease of root initiation and development. The presence of vigorous, high nitrogen shoots is common on young plants, and consequently cuttings sampled from them do not root as well as cuttings made from thin, low nitrogen wood, produced by older plants (13).

Juvenility

Another factor immediately comes into view, inasmuch as we know, through experience, that this is not always the case. It was Gardner in 1929 (11) who noted that in general, the younger the plant, and the nearer to the perifery the cutting was taken, the better the rooting response.

Ease of propagation then, may also be attributed to the existence of the juvenile condition. O'Rourke (16) presented an excellent literature review at the first session of this Society on the importance of juvenility in propagation.

In brief, the juvenile condition is characterized not only by the morphological expressions of leaf shape, size, etc., but also by the inability of the plant or plant part to initiate flower buds, under any set of conditions.

Fritzsche (9) has reported that the juvenile stage of a plant can be fixed by stooling, and consequently the rooting capacity of the plant thereby retained.

On the other hand, Wellensiek (24) has observed that juvenile wood can be obtained from many plant species which have already taken on the mature condition. This juvenile wood which originates from sphaeroblasts, is induced by cutting back and disbudding greenhouse forced stock. These sphaeroblasts arise either from dormant or adventitious buds. The adventitious shoots which develop from these structures root readily when placed under proper conditions.

Auxins As Related to Root Initiation and Development in Softwood Cuttings

Introduction

Root formation on softwood cuttings, as a result of the application of auxin is but one of the many responses in plant tissues derived from auxin applications. Although there have been many theories forwarded as to the reason why the application of auxin to a stem cutting results in a root formation response, the hypothesis generally accepted incorporates the inclusion of an elaborate auxin balance system within the stem.

Fischnich (8) and Liabach (14) in the early 1930's discovered that indoleacetic acid, the active component in many of the commercial rooting powders, was one of the substances in the plant which was responsible for inducing adventitious roots on cuttings.

It is important to note that the movement of auxins in a cutting is generally from the apex to the base, and not from the base to the apex. In other words, the application of a rooting compound to the butt end of the cutting operates in the vicinity of application.

Species difficult to root from softwood cuttings, and which do not respond to the application of hormone powders may have factors other than a deficiency of a natural plant auxin which limits root production. The cutting, after treatment, may initiate roots, but elongation or growth of these roots may not take place because of a deficiency of some root growth hormone or a deficiency of some vitamin.

According to Went (28), a hypothetical natural plant hormone, rhizocaline, manufactured in the leaves of the cutting, results in root initiation and growth in many plant species. Van Overbeek and his co-workers (17) believe that the main function of the leaves on a cutting, as related to root initiation is to supply a source of sugars and nitrogenous compounds rather than a factor X, or Went's rhizocaline.

Cooper (6) theorizes that a factor similar to rhizocaline is equally distributed throughout the length of the stem, and subsequently is mobilized by the auxin gradient in the cutting. In other words, when a synthetic rooting hormone is applied to a cutting, the applied auxin causes rhizocaline to be accumulated at the place of highest auxin concentration at the base of the cutting. The applied auxin, in addition, causes the root inducing rhizocaline to become active. This theory is supported by the fact that the length of many cuttings is directly proportional to the number of roots produced. Thus, a longer cutting, which theoretically contains a larger amount of rhizocaline, has a greater supply available for root production than does a cutting of shorter length.

Many softwood cuttings of certain plant species, on the other hand lack the ability to initiate roots, even if treated with one of the synthetic auxins. Such a cutting, consequently, following the rhizocaline theory, is devoid of this substance.

Anatomical Considerations

Preparation of softwood cuttings

After the wood has been selected, the shoot is now ready to be sectioned. The position of the basal cut is determined by the anatomical make-up of the shoot, and the reaction of the exposed tissues to the surrounding medium.

Suberin formation

At the time the cut is made a wound stimulus causes the secretion of fatty substances into cells immediately adjacent to the cut surface. Under proper condition of aeration in the rooting medium, these substances are oxidized and a suberin layer is formed over the cut surface. Immature tissues as well as poor aeration in the rooting medium may prevent the formation of this suberin layer. Consequently, a typical damping-off reaction may develop, being caused by the ingress of fungi or bacteria into the basal portion of the cutting and subsequent development up-stem.

Position of the basal cut

Chadwick (4), working with a variety of plant materials, propagated from softwood cuttings, concluded that in general, the basal cut should be made one-half inch below the node. From the nutritional standpoint, softwoods sampled at midseason have accumulated carbohydrates at the nodes and the anatomical makeup of the stem is such that positioning of the cut immediately below the leaf insertion would seem to be ideal. If preformed root initials are present, in a particular cutting type, they are usually distributed around the node at the point of leaf insertion.

Origin of adventitious roots

Although it is quite difficult to make a generalization about the specific tissue involved in the initiation of adventitious roots from stem cuttings, it is recognized that in softwood cuttings, the origin lies in the pericycle or outer phloem regions. As the stem matures, this seat of adventitious root production moves inward through the phloem to the cambium.

External Factors Governing Successful Rooting of Softwood Cuttings

Foliage and rooting

Calma and Richey (3) have shown that the amount of leaf area allowed to remain on a cutting will in part determine the extent and amount of root production. Culturally speaking, the amount of foliage allowed to remain on a cutting has in the past been determined by the environmental conditions under which it was to be grown. Water loss and excessive wilting, consequently, have been eliminated in the past by reducing the amount of leaf surface. With the advent of high humidity propagation chambers as well as constant mist systems, however, this need not be the case, in that the retention of a larger photosynthetic leaf area will not only reduce losses of benched cuttings, but may produce a more strongly rooted cutting in a shorter period of time.

The rooting medium

The importance of the rooting medium in regard to the propagation of deciduous shrubs from softwood cuttings cannot be overemphasized. The rooting medium is important from three standpoints i.e.: (a) it provides a method for holding the cuttings in place during the rooting sequence (b) it supplies water and (c) it supplies air. The first point may be satisfied by the use of almost any substance, although the regulation of the water-air ratio places a limitation on many materials such as cinders and heavy gravel.

Air-water ratio

Decker (7) has noted that 19 to 21 percent moisture (expressed as the dry weight of sand) represented a range favoring root initiation and development. In reality the air-water ratio as it exists in any rooting medium is governed by the size, as well as the porosity of the particle. Vermiculite, for example, of the grade having particle sizes ranging from two to three mm in diameter provides an excellent rooting medium provided compaction is avoided and adequate drainage provided.

It has been observed in studies concerned with the effect of size and shape of particles of the rooting media that during periods of high summer temperatures, cuttings placed in a coarse medium produced thin fiberous roots. The coarser medium contained more water and therefore the type of root system produced may be attributed to the existing air-water relationship rather than the size of the particle.

Many nurserymen know that softwood cuttings of many plants when rooted in sand produce brittle, heavy and sparsely branched roots in comparison to flexible, slender well branched roots produced by cuttings in peat moss. Long (15) concludes that low aeration as determined by the water content of the medium accounts for the finer root system produced in a peat moss medium. It is suggested that a more fibrous root system may be obtained from cuttings rooted in sand if the medium is firmed, and if short, slender cuttings are set deep in the medium.

Hydrogen ion concentration and rooting

The hydrogen ion concentration or pH of the medium as it effects rooting of different sorts has been a controversial question. It is known that callus formation is inhibited in media of low pH (below pH 4) or under conditions of high moisture. Cuttings which root profusely in peat moss (of relatively low pH) generally are those which have been sampled from shrubs belonging to the ericaceous group of plants, for instance, azalea, blueberry, and rhododendron.

In general then, the best medium to use for rooting softwood cuttings will depend on (a) the method of watering and (b) the type of plant material being propagated, as concerns acid tolerance. Root formation is based on the rapid formation of a suberin layer along the cells adjacent to the basal cut. Oxygen as well as average moisture and a slightly acid reaction of the medium are requisite to this suberization process for most sorts propagated by means of softwood cuttings.

Temperature of the rooting medium

Propagation by means of softwood cuttings is usually practiced during the summer months, and therefore, the regulation of the temperature in the medium is not an important factor. The stage of maturity of the wood selected for propagation, as well as the plant species determine the optimum temperature range favoring rooting.

Although callusing and rooting are distinct processes, callus production and rooting usually follow in sequence. As concerns temperature, Swingle (23) has noted that callusing appears to have been more active at slightly higher temperatures and lower moisture and oxygen supplies than those inducing rooting of apple.

Light as related to softwood propagation

Growth hormones in plants generally occur only in the presence of light (1). Skinner (19), working with leaf-bud cuttings of rhododendron, increased rooting by supplying an additional seven hour light period of 26 foot candles over the existing 10½ hour day. Stoutemyer and his coworkers (22) have noted that stock plants of *Gordonia axillaris*, (having evergreen foliage), given a light period of 16 hours daily (700-800 foot candles) for one month, yielded cuttings which rooted better than non-illuminated plants and with considerably less callus formation.

Stoutmyer (22) and Chadwick (5) reported that the red-orange end of the spectrum is more important in rooting cuttings than is the blue end of the spectrum.

Avery et al. (1) suggests that the fundamental principle governing these differential plant and cutting responses to light may be attributed to its effect on growth hormones as it in turn indirectly effects the synthesis of carbohydrates.

Mist Propagation

With the advent of mist propagation in greenhouses or out-of-doors, the ease of propagation of all deciduous shrubs from softwood cuttings has been greatly enhanced. However, as with any method, difficulties are encountered.

M. A. Raines in a published report presented in the *American Journal of Botany* in 1940, was to my knowledge, the first to report the use of a humidification chamber for the rooting of cuttings. Meanwhile, Gardner (10), a nurseryman from West De Pere, Wisconsin, was using mist propagation under cloth and glass during the summer of 1939 and 1940.

A portion of the following information has been compiled from work done by Stoutemyer (21), Houston and Chadwick (12), and Wells (25, 26, 27).

Constant mist installations differ from high humidity devices only in the periodicity of water application. In most controlled humidity greenhouses the water applied in an atomized spray runs only when the relative humidity of the house drops below a pre-determined point, for example 85%. Constant mist houses or outdoor frames apply atomized water continuously. In general, the effect on rooting of softwood cuttings placed in either environment is the same, provided adequate drainage exists.

Inasmuch as present emphasis is concerned with the application of constant mist spray either in sash houses or outdoor beds the discussion will be limited to this technique.

Construction

For all constant mist installations the most important single factor is that of drainage. In the construction of the beds, it is of prime importance that they be located in a full sun exposure. If raised benches are used, because of the constant application of water, it is necessary for them to be constructed of a durable building material such as transite, pecky cypress, or concrete. Adequate drainage may be supplied by either spacing holes along the groove in transite plates or by spacing pecky cypress boards and covering the space with a strip of plastic fly screening.

In the construction of ground beds, again, it is essential that good drainage be provided. This may be done by sloping the bottom of the beds to the center, making one end higher than the other, in order that the excess water, not absorbed by the soil can drain to the low end. The bed or bench may then be filled with one of several rooting media. The spacing used for a given nozzle type will depend on its height above the cuttings, available water pressure, and design of beds. Spacing will vary between 18 inches and 8 feet. If at all possible, the water should be strained or filtered before entering the main spray line which is constructed of copper tubing. Provisions for area control should be built into the system in order that men working in one part of the bed will not endanger an area previously stuck and which has been under spray application.

Media

Humidification, in general, tends to minimize the importance of a particular type of rooting medium. The salient feature must be that it permits good drainage. We have had excellent results with the use of the fine grade of perlite or volcanic ash. Wells (25) has reported good results with mixtures of sand and peat (50-50) for azaleas, and sharp river sand for a general line of deciduous trees and shrubs.

Cultural

Preparation of the cutting

The condition of the cutting wood, as previously discussed for general cold frame propagation is a matter of greatest importance in determining the response of plant material to the environment of high humidity. If cutting material from vigorous stock plants is sampled too early in the season, i.e., early May in our vicinity, the shoot is soft and immature, and subsequent placement under a high humidity environment will result in the rooting of the cutting. If the cutting is too hard, i.e., sampled late in the season, excessive callus, light rooting or immediate leaf fall often results. Cuttings of leguminous shrubs are often more difficult to propagate under mist in that they are quite sensitive to high humidity.

At Iowa State, in preliminary studies, we have found that by the application of various growth inhibitors, to stock plants, early in the season we have been able to eliminate in part this rot, which develops in cuttings sampled early in the season. We believe that this may be attributed to the effect of the chemical on hastening the maturity of the wood.

Cuttings are prepared in the usual manner, being from four to six inches in length. Longer cuttings may be made, but there is some difficulty experienced in handling, especially if they are of the slower rooting class of the larger leaved sorts. In general, as we have experienced with different media, the importance of the position of the basal cut is minimized. For most softwood species of shrubs, it is recommended that the basal cut be made immediately below the node, at a point through the leaf insertion. Cuttings are not trimmed, in that rooting, up to a certain point is directly proportional to the amount of foliage retained by the cutting. The basal cut should be clean, and the cutting should not be forced into the rooting medium, in that the damaged cells at the basal end of the cutting will not permit adequate healing, and also will serve as a medium for the growth of secondary pathogens which may ultimately cause the death of the cutting.

Handling the cutting

Of the faster rooting sorts as many as five or six batches can be rooted and transplanted during the course of one summer growing season; of the slower rooting deciduous shrubs only one or two batches can be obtained during the growing period. After rooting has taken place, cuttings propagated early in the season may be transplanted directly into protected beds. In some localities this may be impossible in that high temperatures at the time of transplanting will result in excessive wilting. If this is the case, it is necessary for the nurseryman to harden the cuttings off slowly, by gradually decreasing the amount of water applied. This can be done manually or by the installation of a time clock, which will regulate the time and amount of water applied during any one day. Studies concerned with the prevention of new growth during the rooting sequence by the application of growth inhibitors as well as the application of various anti-desiccants at the time of sticking and pulling have not proven to be commercially applicable.

Cuttings of valuable plants may be put in plant bands in a mixture of sand and peat, replaced in flats and allowed to remain under spray humidification until they have rooted through. They may then be transplanted directly into beds without danger of wilting.

Material propagated late in the season may be carried over winter in plant bands in storage cellars, or by healing-in in mulched, double sash outdoor beds.

Another method of handling this deciduous plant material propagated late in the season which seems to be working for Mr. Richard Fillmore at Shenandoah-Lakes Nursery, makes use of plastic rolls, in which the cuttings are incorporated in sphagnum moss, or vermiculite, secured in bundles, racked in boxes and stored in the cellar for early spring planting.

I realize that I have digressed in the latter part of this talk from principles to techniques. However, I feel that this method of propagating under constant mist will be the generally accepted method of increasing not only deciduous shrubs by softwood cuttings, but will be a means of propagating many other types of cuttings, throughout the season.

LITERATURE CITED

1. AVERY, G., P. R. BURKHOLDER, and H. B. CREIGHTON. 1937. Growth hormone in terminal shoots of *Nicotinia* in relation to light. *Amer. Jour. Bot.* 24: 666-673.
2. BRANDON, D. 1939. Seasonal variations of starch content in the Genus *Rosa* and its relation to propagation by stem cuttings. *Jour. Pomol. and Hort. Sci.* 17 (3): 233-253.
3. CALMA, V. C., and H. W. RICHEY. 1930. Influence of the amount of foliage on rooting of *Coleus* cuttings. *Proc. Amer. Soc. Hort. Sci.* 27: 457-462.

4. CHADWICK, L. C. 1930. The influence of the position of the basal cut on the rooting and arrangement of roots on deciduous softwood cuttings. *Proc. Amer. Soc. Hort. Sci.* 27: 487-494.

5. CHADWICK, L. C. 1949. Some results with the use of opaque structures for propagation by cuttings. *Proc. Amer. Soc. Hort. Sci.* 53: 567-572.

6. COOPER, W. C. 1935. Hormones in relation to root formation on stem cuttings. *Plant Physiology* 10: 789-794.

7. DECKER, S. W. 1933. Moisture relation to the rooting of cuttings. *Proc. Amer. Soc. Hort. Sci.* 30: 596-597.

8. FISCHNICH, O. 1935. Über den ein fluss von B- indolylessigsäure auf die blattbewegungen und die adventivwurzelbilbildung von *Coleus. Planta* 24: 552-583.

9. FRITZSCHE, R. 1948. Untersuchungen über jungendformen des apfel und birnbaumes und ihre konsequenzen fur die unterlagen und sortenzuchtung. *Ber. Schweiz. Bot. Ges.* 58:207-268.

10. GARDNER, E. J. 1941. Propagation under mist. *Amer. Nurseryman* 73 (9): 5-7.

11. GARDNER, F. E. 1929. The relationship between tree age and the rooting of cuttings. *Proc. Amer. Soc. Hort. Sci.* 26: 101-104.

12. HOUSTON, R., and L. C. CHADWICK. 1947. Some results of the effect on controlled humidity, mediums, and watering methods on the rootıng of cuttings of some deciduous and evergreen plants. *Proc. Amer. Soc. Hort. Sci.* 49: 410-415.

13. KEMP, E. E. 1948. Some aspects of plant propagation cuttings. *Jour. Royal Hort. Sci.* 73: 291-305.

14. LIABACH, F. 1935. Über die auslosung von kallus-und wurzelbildung durch B-indolylessigsaure. *Ber. deut. Botan. Ges.* 53: 359-364.

15. LONG, J. C. 1932. The influence of rooting media on the character of roots produced by cuttings. *Proc. Amer. Soc. Hort. Sci.* 29: 352-355.

16. O'ROURKE, F. L. 1951. The effect of juvenility on plant propagation. *Proc. Plant Propagators Soc.* 1: 33-37.

17. OVERBEEK, van J., S. A. GORDAN, and L. E. GREGORY. Feb. 1946. An analysis of the function of the leaf in the process of root formation in cuttings. *Amer. Jour. Bot* 33: 100-107.

18. PRESTON, W. H., J. B. SHANKS, and P. CORNELL. 1953. Influence of mineral nutrition on production, rooting, and survival of cuttings of Azaleas. *Proc. Amer. Soc. Hort. Sci.* 63: 499-507.

19. SKINNER, H. T. 1939. Further observations on the propagation of Rhododendrons and Azaleas by stem and leaf bud cuttings. *Proc. Amer. Soc. Hort. Sci.* 37: 1013-1018.

20. STARRING, C. C. 1923. Influence of the carbohydrate-nitrate content of cuttings upon the production of roots. *Proc. Amer. Soc. Hort Sci.* 20: 288-292.

21. STOUTEMYER, V. T. 1942 Humidification and the rooting of greenwood cuttings of difficult plants. *Proc Amer. Soc. Hort. Sci.* 40: 301-304.

22. STOUTEMYER, V. T. and A. W. CLOSE. 1947. Changes of rooting response in cuttings following exposure of the stock plants to light of different qualities. *Proc. Amer. Soc. Hort. Sci.* 49: 392-394.

23. SWINGLE, C. F. Feb. 15, 1929. A physiological study of rooting and callusing in apple and willow. *Jour. Agri. Research* 39: 81-128.

24. WELLENSIEK, S J. 1952. Rejuvenation of woody plants by formation of sphaeroblasts. *Konikl. Ned. Akad. van Wetenschappen.* Series C55 (5): 567-573.

25. WELLS, J. S. 1951. Pointers on propagation. Further experiences with humidification. *Amer. Nurseryman* 94 (12): 12-14.

26. WELLS, J. S. 1953. Automatic control of humidification systems. *Amer. Nurseryman* 97 (7): 75-77.

27. WELLS, J. S. 1953. Further notes on constant mist. *Amer. Nurseryman* 98 (11): 12-13, 62-67.

28. WENT, F. W. 1938. Specific factors other than auxin affecting growth and root formation. *Plant Physiology* 13: 55-80.

. . . At the conclusion of this paper a brief summary was presented using Kodachrome slides. . . .

* * * *

CHAIRMAN MAHLSTEDE: I believe it is in order to delay the customary discussion period until after the next presentation.

Now it is my pleasure and privilege to introduce a man who has been outstanding in his field for many years. He has been described to me as one of Canada's most able propagators. He has taught at the University of Nanking, China, also at the Ontario Agricultural College at Guelph, Canada, and has been in the nursery business at Cooksville, Ontario for a number of years. It is with great pleasure that I present to you a man of the unusual blend of scientist, nurseryman, and teacher, Mr. Leslie Hancock, Cooksville, Ontario, who will speak to us on the subject of "Shrubs from Softwood Cuttings." Mr. Hancock.

Mr. Hancock presented his paper. (Applause)

Shrubs from Softwood Cuttings

Leslie Hancock
Woodland Nurseries
Cooksville, Ontario, Canada

The purpose of this paper is to describe a method of rooting many types of flowering shrubs, broad-leaved evergreens, etc. in ordinary nursery soil during the months of June and early July without the use of glass or plastic substitutes. This method of rooting softwood cuttings that has been evolved by Woodland Nurseries at Cooksville, Ontario, had its beginning in certain observations made in Nanking, China, during the years 1923-1927. As Horticulturist on the staff of the College of Agriculture, University of Nanking, I found the Chinese flower gardeners using a primitive but very effective method of rooting roses, hydrangeas, and a few other ornamentals in ordinary garden soil. During May, slightly raised beds of pulverized soil about three feet wide were constructed with a narrow rim of compacted soil sufficiently high to prevent any run off when small patches were flooded as required, much like miniature rice paddies. The propagating material used was the short side shoots (laterals) which break into growth from the older wood after the first burst of spring. These shoots were grasped firmly but gently with the thumb and forefinger and removed by a downward tearing motion, hence they were not strictly cuttings at all. After removal they were laid on flat bamboo woven containers and carried to a shady spot where the lower torn part of the old bark would be clipped away with scissors, and in the case of roses, the flower bud would be clipped away at the same time. They were then carried to the propagation bed where water would be poured on to a small area just sufficient for immediate needs. This was important because if water were poured over a larger area than necessary, the unused portion would be spoiled for insertion of the next batch. At the same time, a liberal amount of water was used in order that the shoots would stick in without injury, and the planters aimed to have all the shoots pushed into the mud before all the water had completely drained away. As planting of each batch was completed, they would be immediately shaded with large rectangular stiff mats woven from flattened reed strips. These mats had a curved form which made them very suitable for laying over bamboo rods fastened to short posts along either side of the beds. The close woven mats allowed practically no direct sunlight to pass through, so that during the hot part of the day only indirect light reached the cuttings from the sides. After the "cuttings" had been pushed into the mud, no further watering was given, apart from natural rainfall. Toward evening, about an hour before sundown, the shades were all removed and carefully stacked. The following morning, about two hours or so after sunrise, they would all be just as carefully returned to their positions on the supporting bamboo rods. This operation was not considered necessary as long as the dew remained on the foliage. The daily covering and uncovering process was followed scrupulously for three or four weeks and the drying mud would even be starting to crack when by the appearance of the plants it was evident that rooting was taking place. As each batch appeared to be sufficiently rooted, they were taken up and transplanted into small pots, and I well remember the care that was taken to keep the little block of soil adhering to the tender roots of each young plant intact.

Alongside this native technique, I started to apply my western inspired theories of propagation. Without going into details, it is enough to say that with my youthful over-confidence plus my lack of long term experience of local conditions, the results of my efforts were far from impressive, and in the end I was forced to admit that these resourceful oriental propagators really "had something."

The outcome of all this was that since our return to Canada, I have attempted to work out, under our local conditions, the principle used so effectively by the Chinese. I had no bamboo poles and no reed mats, so used rods of 1" x 2½" lumber over which I draped heavy burlap. There is less summer humidity in Ontario than in Nanking and the first results were sad. The cuttings were often flattened to the ground by hot, dry, dusty winds and would not rise again. Our light sand did not puddle like the Nanking soil, and the making of an earth rim on each side of the beds proved to be impractical and time consuming. Finally, I hit on the idea of a light box frame which would keep out the wind and when sunk into the ground an inch or two, would keep the water in for the flooding operation. The burlap cover was retained as the best shading medium coming nearest to the Chinese mats. The burlap was fastened to a strip of wood nailed along one side of the frame but at first we had an uncovered one inch strip of air space along the upper edge of each side of the frame for the ventilation which I considered so necessary. During the day the burlap was made taut by slipping it over finishing nails set at fairly close intervals along the opposite side of the frame. An additional advantage of the burlap was that being light it was easy to remove and replace. After the development of this frame, our results steadily improved.

When my sons joined me in the business, production by this new method was good on the whole, but far from satisfactory for certain items. Gradually we found that frequent sprayings of the burlap during the hot part of the day gave increasingly better results, and finally we closed the air gaps, eliminating all chance of entry of outside air, except through the moisture laden burlap. Double shading of items that tended to wilt helped greatly. The extra shading was not a second layer of burlap, but ordinary 3′ x 4′ shades of builders lath, over which was tacked a square of burlap. Uncovering the frames towards evening and re-covering the following morning continued to be standard practice; in fact, we consider it an indispensable part of the technique.

Our method is now so far removed from the original Chinese practice which sparked its development, that it would be better styled the "burlap-cloud method." Emphasis must also be given to the fact that it has been evolved to meet our own peculiar conditions and might not work at all with some other soils and subsoils along with differing climatic conditions. Our soil is a fine dust or powder, and not a true sand. Without liberal additions of humus, it tends to get very tight and lacking in aeration. We have a high water table held up by an impervious layer of clay four feet down, so we have had to drain carefully. Yet we think this high water table is one of the reasons for successful rooting. We give our results and experience only for what it is worth in the light of these qualifying conditions.

I will now describe the method in detail:

1. *Preparation of Soil:* Reasonably fertile soil that has received no fertilizer for at least one year should be used. Land should be well graded with a fall of about one foot in a hundred feet to ensure that no surface water can collect anywhere. We have sunken cross paths every sixty feet into which the water from the slightly sunken paths between the beds can drain without traversing the whole length of the field. Beds of the same widths as the frames to be used are laid out systematically and raised about two inches. Frames are then set into position in a continuous row, and some adjusting with a spade will be necessary to lower them to the level of paths between beds. Starting at one end of a series of frames, the soil is then removed from a half frame to a depth of about two inches below the lower edge of the frame and the 3′ x 6′ sieve set into position. Soil from the next six feet of frame is excavated to the same depth and passed through the sieve which will automatically give about four inches of sifted soil, and the process can be continued systematically from frame to frame. This sifted soil is levelled out with a spirit level, leaving about seven or eight inches vertically between the soil and the top of the frame. Soil should now be thrown against the outer lower edges of the frames to prevent water leaking out during planting operations. Each frame has its own burlap cover which is tacked into position along one side of the frame and securely fastened to the other side of the frame by slipping over finishing nails exposed about 1 inch.

2. *Collecting cuttings:* Something should now be said regarding the handling of the cuttings. A heavy hot hand bruises the cuttings. They should be removed lightly in small handfuls, and then we stand them upright in twelve or fourteen quart pails with about two inches of water in the bottom. We have not noticed any appreciable difference in the rooting due to the time of day they are gathered. If there is an advantage, however, it is in the evening when the shoots need not be placed in water, and can be carried to the propagation beds in a completely turgid condition. There is definitely a disadvantage in leaving the cuttings with water in the pails too long, particularly in very hot weather. In fact, leaving them in water overnight has resulted in serious losses. In my opinion, we would do well not to leave the cuttings standing in water more than one hour. Contrary to accepted practice, we do not remove any foliage, except in such cases as *Cornus florida* and the various magnolias, which have thin large leaves. Cuttings are stuck—basal leaves

and all. The air spaces made by the passage of lower leaves into the soil allows oxygen to enter, and lessens the chance of decay at the base of the cutting due to action of anaerobic bacteria.

3. *Timing:* There are two questions as regards timing. One is the time of year or date, and the other the stage of maturity of the cutting. In my opinion, the advantages are all in favor of the cuttings made early in the season. This is the reason for taking side shoots or laterals as these are the first obtainable. With the exception of *Hydrangea arborescens,* which are taken the second or third week in May, we start operations about June 1st-3rd, and would start earlier if we could. Hot weather, however, is essential, and before June 1st cold spells and even frost are possible with us. As to timing in regard to maturity, the length of a shoot gives some indication as to whether it is ready for gathering. Early shoots of Golden Mockorange should be about four inches long. Forsythias should be six inches long. An experienced propagator has to decide whether the young wood requires another two or three days of growth before gathering, or, in other cases, may consider they have grown too much and should have been gathered a day or two earlier. Because cuttings in sufficient quantity cannot be obtained at any one time, we often have as much as three or four batches of any one variety. In the case of the Golden Mockorange, all the early cuttings are of side shoots but all the later ones are made by cutting five inch tips from the strong young canes. Both root equally well with us and there is no magic as to what part of the parent plant the cuttings come from.

4. *Wounding:* In 1952 we tried wounding by making longitudinal slips through the bark near the base of some cuttings with some success. One of the most spectacular results was 100% rooting of some fifty cuttings of *Cornus florida rubra.* This year we repeated the experiment with the same variety only to lose most of them. Weather and soil conditions were not as favorable this year, but looking back, I am inclined to blame the failure on the condition of the parent plants at the time of taking the cuttings. In 1952 the plants from which the cuttings were taken had been recently moved and the shoots were short and sturdy, whereas this year cuttings were taken from plants that were well established and very hot weather had caused the growths to be long and soft.

5. *Planting the cuttings:* Water is poured on from large cans before planting, enough water to ensure complete saturation to the full depth of the sifted soil. The cuttings are pushed into the mud before the water has had time to drain away. We set cuttings close enough to get from forty to seventy-five per square foot. Any closer would give insufficient room for later growth. Cuttings are inserted to about half their length, or until their easy downward movement is stopped.

6. *Aids to rooting and disease control.* We have not used plant hormones but probably should have done so. Our greatest benefit has come from the disinfectant Tersan. At one time, batches of *Cornus elegantissima* were a complete failure but since coating the bases of the cuttings

with a light dusting of Tersan, we have had complete success. We use sulphur dust for controlling surface rots, and also Tersan. Aphis will ruin cuttings of most spiraeas unless they are sprayed with soap and Blackleaf 40, soon after inserting in the frames. Cuttings of such plants as *Viburnum Carlesii* and *Rosa hugonis* must come to the frames free of black spot or they will not root.

7. *Spraying the burlap curtains:* Water is laid on from taps centrally located throughout the length of the area reserved for the cutting beds, one tap with hose servicing 60 feet of cutting beds in either direction. At intervals of perhaps half to three-quarters of an hour, one of the planting crew sprays the burlaps carefully, making sure that each section is as uniformly moistened as possible but spraying a section no longer than is necessary to accomplish this. We consider it bad practice to drench the curtains unnecessarily and as little water as possible should drip through on to the cuttings. The idea is not to allow the burlap to get completely dry. On hot days of low humidity or very windy days, spraying may have to be done as much as eight to ten times, but on most days about six sprayings are sufficient, and on cloudy days with high humidity hardly any spraying is necessary. Also, on cloudy wet days the cuttings may remain uncovered the whole day. The worst days are when there is a hot dry wind and strong sunlight. At first sight, hand spraying would seem an expensive procedure and we have toyed with the idea of automatic spraying only to realize that such an installation would require considerable watching to be correct for all types of weather. One boy, after proper coaching, can spray a lot of burlap covered frames in about ten minutes. The hose is pulled along a central path between the propagation beds, the operator returning with the nozzle to turn off the tap when all areas are uniformly moistened.

8. *Pre-rooting care:* In fine weather all frames are uncovered about one or one and a half hours before sundown, and re-covered the following morning around 8:30 or 9:00 A.M. In wet or very cloudy weather, the burlap shades are left off. If the tips of the cuttings droop, double shading is given with 3′ x 4′ lath shades covered with burlap. When damping off or other disease or insect attacks are evident, we dust with sulphur or other standard controls, and this work is best done at a daily early morning inspection before placing the burlap shades on for the day. Different treatments are necessary for different types, and only by a daily watch is it possible to determine the correct cause for progress or failure.

9. *After rooting care of cutting beds:* Spraying is discontinued when cuttings are properly rooted and the next step is to gradually accustom them to open air growing conditions. The burlap can be left off for longer periods in morning and evening, but usually we find that rooted cuttings rapidly need more sunlight, and either we remove the burlap and lay lath shades over the frames, or else we remove the frames altogether and set up lath shading only. Sometimes, after a week or more of

partial shading, complete sunshine can be given for the rest of the season. However, there are some plants such as *Daphne cneorum* which may suffer if given full conditions too quickly and some, such as Golden Mockorange, have to be carried well into September before full sun can be allowed. Usually, by the fifteenth of September, all frames and shades will have been removed. From then until November most of the propagations grow vigorously, often too vigorously for their own good, so that we have to clip the tops of the tallest to allow all to develop uniformly.

10. *Winter protection:* As suggested above, one of the dangers comes from late fall growth, and we have lost whole batches of *Weigela* and *Viburnum* from a sudden hard ground frost. The upward thrust of frozen earth splits the soft bark at the ground line and the lesions rapidly cause the death of the whole plant. In 1952 we had a splendid lot of *Viburnum tomentosum plenum,* well rooted, and some of them a foot high. Due to such a frost, we lost all but about ten percent of them. This year we obtained another good crop, and to prevent this happening again, we lifted them during October and heeled them in a frame. Then when the first hard frost came, we had them properly protected with litter. It yet remains to be seen whether we shall be able to bring them through in good shape. Another precaution for wintering is to deepen the pathways between the beds, throwing the soil between the cuttings to raise the beds in the center. Practically all our production is wintered in this way.

Types and Varieties Grown:

We now raise over one hundred varieties of plants by this method in the following genera:

Azalea	Euonymus	Pachysandra	Sambucus
Buddleia	Forsythia	Philadelphus	Sorbaria
Ceanothus	Hydrangea	Pieris	Spiraea
Chaenomeles	Hypericum	Potentilla	Symphoricarpos
Clethra	Iberis	Prunus	Syringa
Cornus	Kerria	Pyracantha	Viburnum
Cotoneaster	Kolkwitzia	Rhodotypos	Weigela (Diervilla)
Daphne	Ligustrum	Ribes	
Deutzia	Lonicera	Rosa	

Of these, we get 100% results with easy rooting forms such as *Buddleia, Ceanothus americana, Clethra alnifolia, Deutzias, Euonymus fortunei, Forsythias, Kerria, Ligustrum, Pachysandra, Sambucus* and *Weigelas.* With care as to special needs, we can usually get 90% or more in the following: *Cornus elegantissima,* and *C. spaethi aurea, Hydrangea arborescens* and *H. paniculata, Lonicera zabeli, Philadelphus* all varieties, *Potentillas* (early batches only), *Rhodotypos, Ribes, Spiraea bumalda* varieties, *Symphoricarpos,* and *Viburnum tomentosum.* Fickle varieties which would average from 50% to 75% rooting over several years are *Daphne cneorum, Euonymus alata, Syringa persica, Viburnum tomentosum plenum.* Poor results and frequent failures are experienced with the following: *Chaenomeles, Cotoneasters, Prunus glandulosa, Spiraea arguta* and *S. prunifolia,* and *hybrid lilacs.*

To sum up, the advantages and disadvantages of the method as we see it are as follows:

Advantages:

1. *Economic:*
   - (A) The rooting of cuttings in ordinary soil not only saves considerable expense in preparation of soil medium but also eliminates the costly "potting up" stage.
   - (B) Overhead cost of equipment is very low consisting of a light frame made from one inch boards, a supply of 40″ width medium heavy burlap, a large ¾″ mesh sieve and the usual garden tools. Most nurseries are already piped for water.
2. *Natural:*
   - (A) Cuttings receive healthful sunlight and moisture at the right times and in the right amounts. (Moist burlap simulates cloud).
   - (B) When rooted there is no check in their growth which continues uninterrupted until late Fall.

Disadvantages:

1. Danger of loss from toxic soil conditions, rots from soil bacteria or fungi difficult to completely eliminate.
2. No control over adverse weather conditions such as extreme heat, drouth, or heavy rain.

. . . At the conclusion of his paper Mr. Hancock continued the discussion by the use of slides.

* * * *

MR. HANCOCK: The basic design for the individual rooting frame is very simple. We construct a 12′ x 3′ box, using 10″ x 1″ red cedar boards. The box is carefully squared and fitted with a centrally located cross bar, also constructed of red cedar, which is used to facilitate transfer and placement. Each frame has its own curtain which is cut 8 inches longer than the unit because we find that it shrinks. The burlap is tacked in position along one side of the frame and securely fastened to the other side of the frame by slipping it over finishing nails exposed about one inch.

MR. ROSCOE FILLMORE (Fillmore's Valley Nursery, Nova Scotia, Canada): What direction do you run the beds?

MR. HANCOCK: We run them approximately north and south. With such an arrangement there is a steady movement of light from one side of the frame to the other, and therefore all cuttings get some light during the course of the day.

After the frame has been located, a 6′ x 3′ sieve is set into position. Before the soil from the adjacent six feet of frame is excavated to the same depth, we compact the floor, because we believe moisture is a very

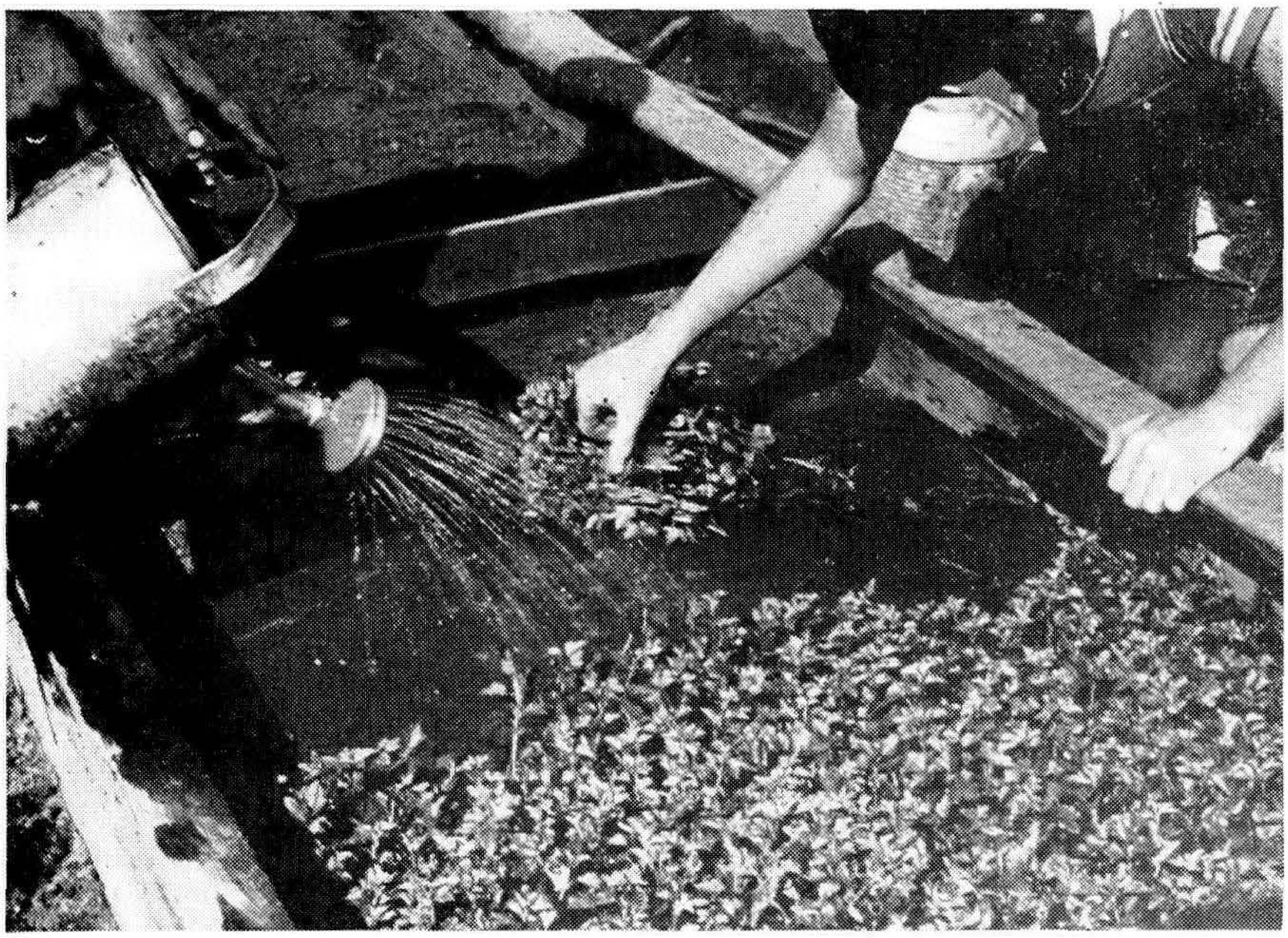


Fig. 1. Inserting *Ribes alpinum* cuttings.

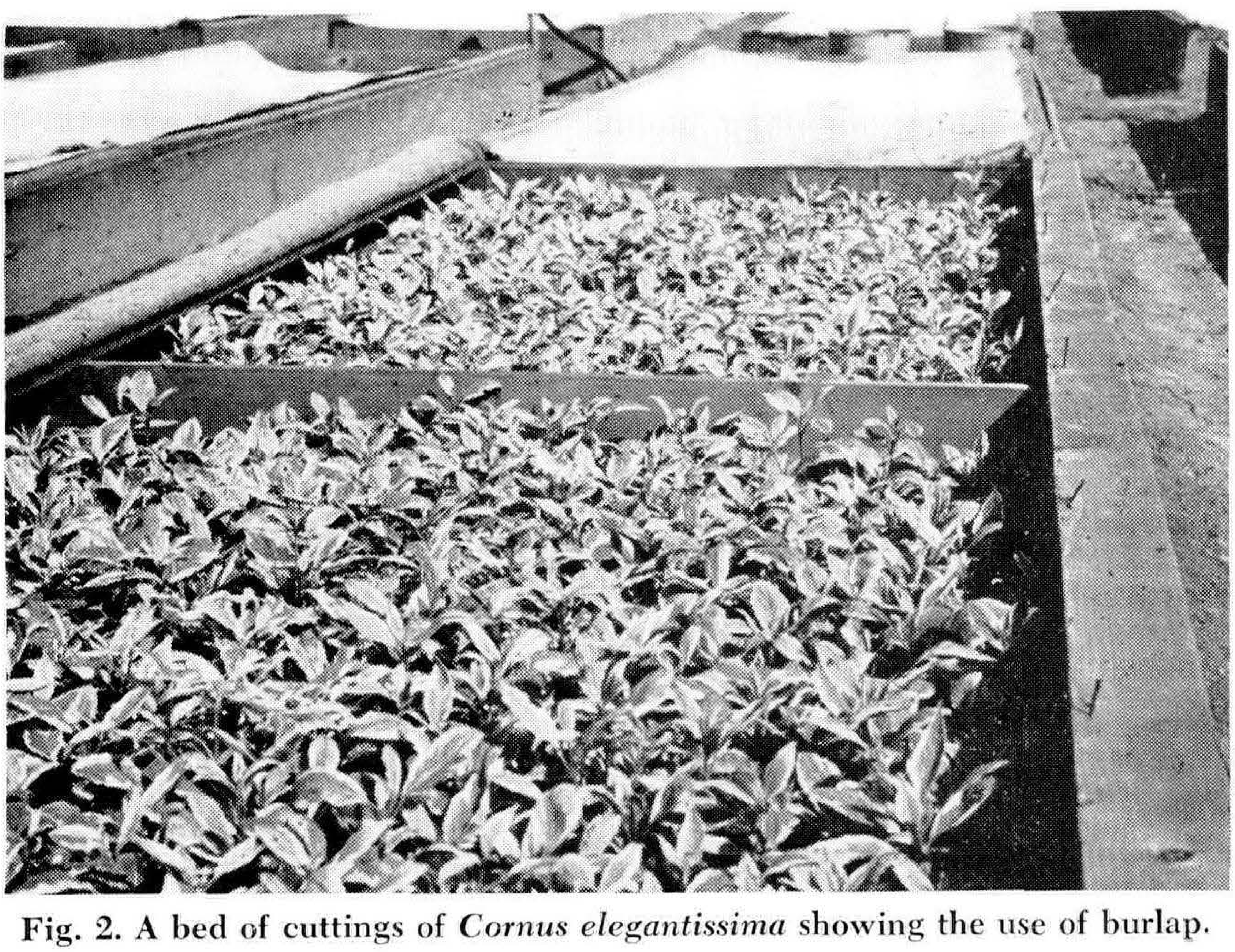


Fig. 2. A bed of cuttings of *Cornus elegantissima* showing the use of burlap.

Fig. 3. Two sixty-foot beds of golden mockorange with the frames removed.

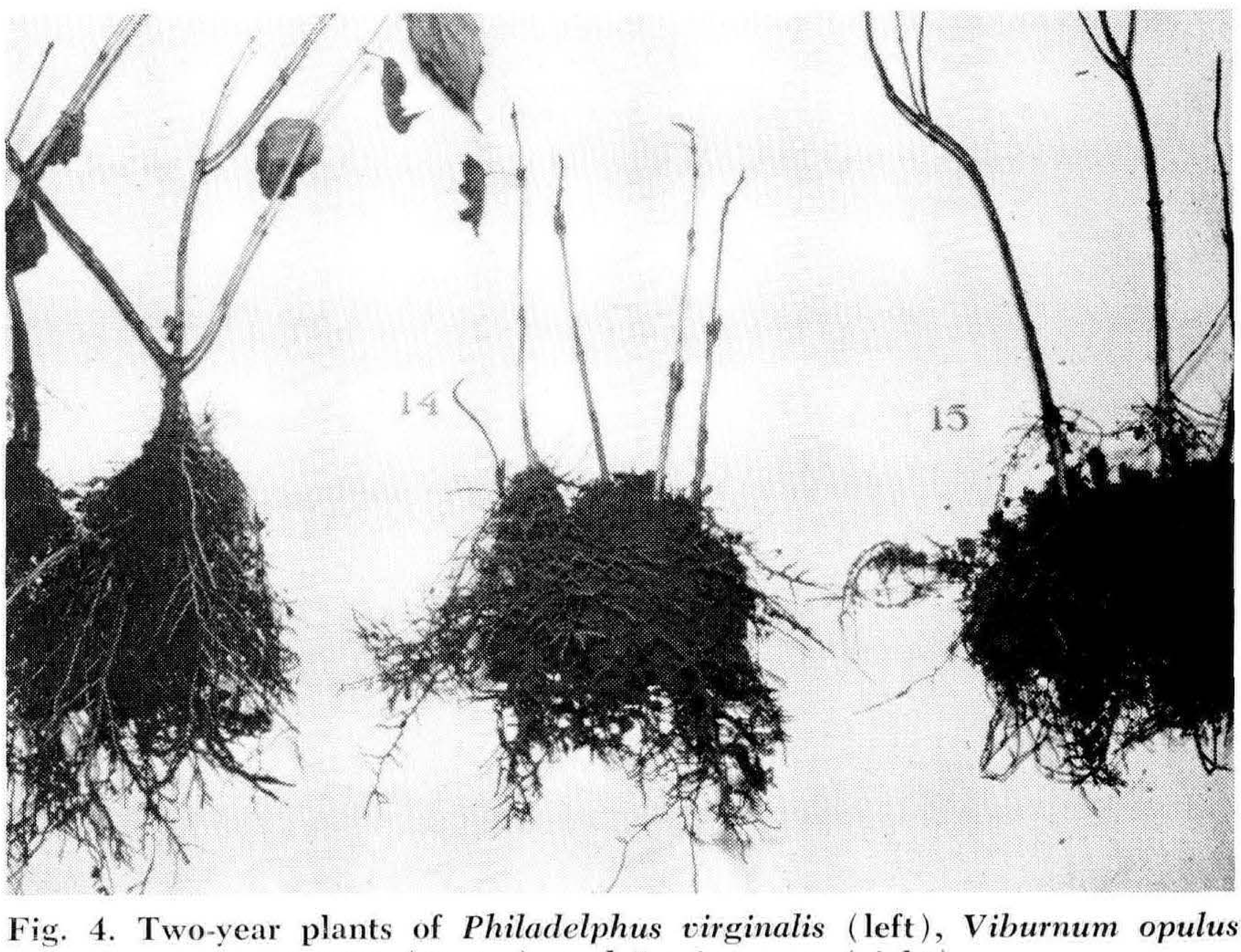


Fig. 4. Two-year plants of *Philadelphus virginalis* (left), *Viburnum opulus nanum* (center), and *Lonicera sp.* (right).

important factor. However, it has been pointed out that on some soils and sites this might be fatal. I am giving this for what it is worth under our conditions. The soil is next passed through the sieve, automatically giving us about four inches of sifted soil. The process is then continued systematically from frame to frame.

When the soil has been sifted into the entire frame, water is poured on from a large watering can before planting, and in enough quantity to completely saturate the medium to the full depth of the sifted soil layer.

At this point I should mention that in the early phase of rooting we spray the burlap curtains about six times on the average day. You might ask why we don't have a timing device. Actually it doesn't take a boy more than five minutes to wet the burlap. The idea is not to allow the burlap to get completely dry, although it should be nearly dry by evening in order to reduce chances for the development of damping-off organisms.

MR. HOOGENDORN (Hoogendoorn Nursery, Newport, R.I.): What do you use to wet the burlap?

MR. HANCOCK: Just ordinary hose, and lots of power. With one inch hose we can do this in a very few minutes.

MR. ROSCOE FILLMORE: You are not getting drip?

MR. HANCOCK: The operators are told not to put too much water on. They spray the burlap when it begins to dry and as often as it is necessary throughout the day. They are cautioned not to put so much water on that they drench the cuttings.

MR. JACK SIEBENTHALER (The Siebenthaler Company, Dayton, Ohio): Do you feel that it would be advantageous for you to treat the burlap shading with a preservative?

MR. HANCOCK: Yes, I think it would be all right. I have been very cautious however, about using it, although I know these copper preparations do preserve the burlap. I think it would be advantageous.

MR. WILLIAM FLEMER (Princeton Nurseries, Princeton, N.J.): Of what weight is the burlap that you use?

MR. HANCOCK: I tried No. 10 ounce and it proved to be too heavy—8 ounce allowed too much light through so I figured No. 9 ounce was about right.

PRESIDENT WELLS (D. Hill Nursery, Dundee, Ill.): I would like to ask Mr. Hancock if he has ever tried plastic sheeting instead of burlap and what he thinks about the possibilities.

MR. HANCOCK: I returned to the orthodox mind recently and said the Chinese method is no good. I made up a box and put a piece of plastic over it and stuck a large batch of hydrangea in it. I said, "that is fine, this is nothing but the French bell jar." I took it off in 48 hours and the cuttings were all dead.

MR. SHAMMARELLO (South Euclid, Ohio): Do you attribute that to the heat held in the frame by the plastic?

MR. HANCOCK: I think movement of air is very vital. I quite agree with the new methods and believe the day will come for this type of work to be done mostly outside, provided you use fungicides to protect the cuttings from rot fungi.

MR. HOOGENDOORN: Do you strip the leaves from the cutting before you stick it?

MR. HANCOCK: We do not remove a piece of foliage from the cutting. We stick it directly into the mud before the water has had time to drain away, making sure that our fingers do not contract the medium. If this were allowed to happen we would block the hole, thereby giving us trouble because of poor aeration. The depth of sticking depends on the size of the cutting; for example, to a depth of one half if the cutting is short, and a third if it is longer.

As for the business of stripping the cutting; we don't even take the tails of bark off. The tails curl up and the cutting grows just the same.

(Slides were shown to demonstrate stands obtained for a number of type and varieties which were successfully propagated by this method.)

MR. HOOGENDOORN: Have you tried rooting magnolias yet?

MR. HANCOCK: I have, but I have not been successful at all—but I may yet.

MR. HOOGENDOORN: How do you make mock-orange cuttings, with a heel, as you have pictured it?

MR. HANCOCK: The boys gather them very fast, stripping them from the stock plants as rapidly as they are able, until they have a handful. They then put the cuttings in a pail of water, so that *only* the butt ends of the cuttings are wet. I will admit that you can make a mess of the stock block.

MR. HOOGENDOORN: Now, if you cut that block down in the winter you will get young growth the next year. You may have lateral shoots, or you may have straight shoots. How do you get the heels from these?

MR. HANCOCK: I don't quite understand your question, because it is possible for you to gather these cuttings judiciously. If you have a big field of viburnum, for instance, you don't need to take more than one or two cuttings from each plant. By fall, that will be beautifully healed over and it will be difficult for you to see it.

MR. HOOGENDORN: If you have a cut-back shrub it will make one straight shoot.

MR. HANCOCK: That is the Holland method to cut them back. That is your business.

MR. JACK HILL (D. Hill Nursery, Dundee, Ill.): What is your date for collecting cuttings of *Euonymus Fortunei vegeta*?

MR. HANCOCK: June. They grow fairly fast and early, and consequently we start to cut them about the third week in June.

MR. HILL: Mr. Hancock, have you ever encountered bud dormancy that precluded the growth of this plant in the first season?

MR. HANCOCK: None whatsoever.

MR. HILL: They continue to grow?

MR. HANCOCK: Except that they jump ahead. I have gathered twice as much cutting material off the next year as I put cuttings in, and I still have a bushy plant.

MR. DONALD S. McCONNELL (Port Burwell, Ontario): Have you ever dipped any of the cuttings in sulfur dust before inserting them in the frame?

MR. HANCOCK: That is a very important point, and since I belong to the Propagators Society I have to give you the whole picture. Until we found a suitable fungicide, we couldn't root cuttings in the manner I have described, on a commercial scale. The fungicide we have found most acceptable is Tersan.

PRESIDENT WELLS: Do you dip the entire cutting in Tersan?

MR. HANCOCK: I merely wet the cutting, shake it, and apply a light coat of the fungicide dust. We actually had 100% rooting the first time we attempted to root *Cornus Florida rubra.* In this procedure I slit the basal portion of the cutting, a technique that I learned from someone here the year before, and dusted that portion in order to prevent any rots from developing. We got 50 out of 50 to root. Now this year, with our technique seemingly perfected we were going to make money. We put in several hundred cuttings; we still got 50 to root.

Our poor results however can be explained. The cuttings we took the year before were taken from imported plants, which had been moved in the spring, and consequently had mostly short, hard cuttings. They went into the frame in the best possible condition. Those stock plants were then put out in the field and religiously fertilized. This year they grew very rapidly. As a result, the cuttings that we made this year were quite long and of soft, succulent wood, which resulted in a very poor stand.

DR. W. E. SNYDER (Cornell University, Ithaca, N.Y.): How many of those first 50 rooted cuttings are still living?

MR. HANCOCK: Twenty are still alive. We found that they are quite hard to overwinter and believe that one way that we might be able to handle them would be to pot them up, in order to re-root the cuttings before overwintering them in the greenhouse the first year.

MR. HOOGENDOORN: When do you remove the frames?—the spring following rooting?

MR. HANCOCK: No, as soon as they are rooted in most cases. If we want to shed the burlap, which incidentally gets rotten in about a month, we rip it off and just lay shades over and watch the frame. As soon as the cuttings are well established the box is taken away. Of course, this invites very open conditions during the winter.

There are occasions in which we allow the frames to remain in place over winter. If this is done, it introduces the danger from melting snow, which may fill the box with ice, to give us some winter injury.

MR. HERBERT TRAUTMAN (Trautman Nurseries, Franksville, Wis.): You could raise your frames slightly in place and still furnish protection as well as drainage.

MR. HANCOCK: This is possible, in fact I have placed small blocks of wood under some frames in order to allow the water to drain out. I believe for items that root slowly it is an excellent idea to leave the frames in place for another season. I have filled a few frames with materials similar to moss, which has been used to good advantage.

QUESTION FROM THE FLOOR: After the cuttings have been rooted how do you avoid winter injury?

MR. HANCOCK: We try to avoid it by all sorts of methods. Of course, winter injury is a big danger with this method of propagation. I should have pointed out in my list of disadvantages that the cuttings may get into too much growth late in the season, especially if you don't watch them carefully. Though we use soil for growing them, we do not dare apply a lot of liquid fertilizer the first year. It is up to whoever puts them in the field to see that the cuttings go into well-prepared soil.

MR. HOOGENDOORN: Do you ever get a lot of stem splitting?

MR. HANCOCK: Our two main problems during the winter are frost heaving, and as you have mentioned, stem splitting at the base. By taking them up before the frost comes, and heeling them in, in protected frames, I think we have overcome that danger.

MR. HOOGENDOORN: Why couldn't you mulch the cuttings in place, late in the fall?

MR. HANCOCK: We also do that. In this connection we have used both leaves and shingletow. When either is used as a mulch it also is placed in the path in order to insure drainage in addition to affording protection for the first inch or two of the cutting bed proper. I have discovered that with weigela and viburnum we are particularly bothered. I lost a beautiful batch of *Viburnum tomentosum plenum* last year. This year I have already taken them up before any danger of a heavy frost.

PRESIDENT WELLS: I would like to ask Mr. Hancock to expand a little on the question of over-wintering. I would expect a very high mortality.

MR. HANCOCK: Well, Mr. President, there isn't any very high mortality. The only argument I can make to that is that we have not lost one day of growing opportunity of that plant by transferring it to a pot or other location. At one time when my good friend Bill Stemens was coming to us and saying, "Why do you want to transplant that?", it gave me one idea. I didn't. The result is now, we can grow these cuttings as well as he can.

PRESIDENT WELLS: What kind of winter conditions do you have at Cooksville?

MR. HANCOCK: We get 10 degrees below zero occasionally, and we will experience some winter killing. Take *Viburnum tomentosum plenum* for instance, which is very susceptible to winter injury although it has very hardy basal buds. I think the problem can be overcome by putting on plenty of mulch. Another factor is drainage. We haven't in our whole nursery one spot where water will stand in a puddle, and I don't believe it should, in any nursery.

CHAIRMAN MAHLSTEDE: Are there any further questions you would like to direct to Mr. Hancock?

PRESIDENT WELLS: If not, Dr. Mahlstede has a few slides which we did not have a chance to see and which I think we should look at, if time permits.

CHAIRMAN MAHLSTEDE: Since we have only a short time remaining I will present a few slides showing the results of only several of the experiments being carried on at Iowa State College concerned directly with plant propagation.

. . . The summation of information presented is as follows: . . .

Pretreatment studies concerned with the application of various growth inhibitors to stock plants and cuttings, in order to hasten maturity of sofwood cutting material indicate, that under proper environmental conditions, maleic hydrazide can be used effectively. It is advisable however, not to use this chemical until further studies have been made, in that permanent injury to plants may result under certain conditions.

Use of Fermate (2 oz. per gallon of water) and Wettable Arasan (1 oz. per gallon of water) applied to stock plants before sampling softwood cuttings of *Lonicera tatarica* significantly reduced bench losses. Experimental results further indicate that a fungicide stock-plant spray, in conjunction with a solution dip, prior to insertion of the cuttings in the bench will generally result in negligible losses of cuttings propagated under high humidity and temperature conditions.

Studies concerned with the application of various growth inhibitors to a variety of plant materials, in order to inhibit terminal and lateral growth during the rooting period gave negative results. Use of maleic hydrazide, alpha cyano-beta-2,4-Dichlorophenyl Acrylic acid, and its sodium salt at concentrations of .05 and .1 percent did not significantly reduce the total amount of new growth produced by a number of softwood cutting types. In general, terminal elongation of shoots was partially inhibited by the use of the higher concentration of the growth regulator which was accompanied by the production of many axillary shoots. The one tenth percent concentration of all chemicals used noticeably reduced the total number of roots produced from softwood cuttings of *Ligustrum amurense,* and *Cornus stolonifera,* as compared to the control treatment.

The effect of soil conditioners on the rooting and subsequent survival of field planted hardwood cuttings was studied. Apical, basal and combination applications of Aerotil (dry form) noticeably increased rooting and survival of fall planted hardwood cuttings of *Lonicera tatarica.* Surface and combination applications of the dry form significantly increased stands of *Ligustrum amurense.* No increase in survival was obtained from applications of Aerotil (dry and wettable forms) to cuttings of *Cornus stolonifera.* The beneficial effects derived from the use of this substance on heavy soil types may be attributed to improved aeration.

CHAIRMAN MAHLSTEDE: Now our time is gone and I want to thank you very much for bearing with us this afternoon. Especially would I like to express our gratitude, and I think I speak for the group, to Mr. Hancock, who gave us one of the most interesting presentations of the entire meeting.

The assemblage arose and applauded.

The session recessed at 4:00 p.m.

EDITOR'S NOTE: Mr. H. F. Harp of the Dominion Experimental Station, Morden, Manitoba, Canada, was unable to be present and because of the lack of time his paper was not read. However, it is included in the Proceedings as was announced at the conclusion of the panel discussion of the propagation of softwood cuttings.

Root Inducing Substances

H. F. HARP
Dominion Experimental Station
Morden, Manitoba, Canada

INTRODUCTION

It is a well known fact that stems of plants generally bend towards light. Darwin (3) was the first to demonstrate that some "stimulus" was trainsmitted from the tip to a region further down the axis of seedlings exposed to one-sided illumination. The response of the plant to this "stimulus" caused the axis to bend toward light as a result of an unequal rate of growth.

To the inquiring mind, there were many questions in connection with this phenomena which were yet unanswered. It was for Boysen Jensen (1) some years later to demonstrate that Darwin's "stimulus" was a chemical substance which moved through the tissues of the plant.

In 1928, F. W. Went, (4) working with biochemists at the University of Utrecht, described a quantitative method for determining the presence ticeably reduced the total number of roots produced from softwood cuttings of *Ligustrum amurense,* and *Cornus stolonifera,* as compared to the control treatment.

The effect of soil conditioners on the rooting and subsequent survival of field planted hardwood cuttings was studied. Apical, basal and combination applications of Aerotil (dry form) noticeably increased rooting and survival of fall planted hardwood cuttings of *Lonicera tatarica.* Surface and combination applications of the dry form significantly increased stands of *Ligustrum amurense.* No increase in survival was obtained from applications of Aerotil (dry and wettable forms) to cuttings of *Cornus stolonifera.* The beneficial effects derived from the use of this substance on heavy soil types may be attributed to improved aeration.

CHAIRMAN MAHLSTEDE: Now our time is gone and I want to thank you very much for bearing with us this afternoon. Especially would I like to express our gratitude, and I think I speak for the group, to Mr. Hancock, who gave us one of the most interesting presentations of the entire meeting.

The assemblage arose and applauded.

The session recessed at 4:00 p.m.

EDITOR'S NOTE: Mr. H. F. Harp of the Dominion Experimental Station, Morden, Manitoba, Canada, was unable to be present and because of the lack of time his paper was not read. However, it is included in the Proceedings as was announced at the conclusion of the panel discussion of the propagation of softwood cuttings.

Root Inducing Substances

H. F. HARP
Dominion Experimental Station
Morden, Manitoba, Canada

INTRODUCTION

It is a well known fact that stems of plants generally bend towards light. Darwin (3) was the first to demonstrate that some "stimulus" was trainsmitted from the tip to a region further down the axis of seedlings exposed to one-sided illumination. The response of the plant to this "stimulus" caused the axis to bend toward light as a result of an unequal rate of growth.

To the inquiring mind, there were many questions in connection with this phenomena which were yet unanswered. It was for Boysen Jensen (1) some years later to demonstrate that Darwin's "stimulus" was a chemical substance which moved through the tissues of the plant.

In 1928, F. W. Went, (4) working with biochemists at the University of Utrecht, described a quantitative method for determining the presence of these chemical substances, which were later to be called plant hormones, or auxins. Went's original method of using agar blocks and oat seedlings to determine hormone concentration is essentially the same quantitative method used in the laboratories at the present time.

Although the concept of growth regulators, or hormones was not advanced until comparatively recent times, horticulturists and plantsmen through the centuries have noted the phenomena of apical dominance. Many references point to the fact that lateral buds appear to be held in a quiescent or dormant state in the presence of a terminal bud; it was postulated that this was due to an inhibiting substance, of a chemical nature, which was produced in the developing apical growing point.

As a result of continued investigations with growth regulating substances Went (5) further suggested that another group of plant hormones, specific for various growth processes were active in the plant. One of these, namely rhizocaline, which is produced in the leave of plants, theoretically is required for root production on cuttings. In addition Went postulates that this substance, in order to be active, must be accompanied by other natural plant auxins, one of which is indoleacetic acid.

It has been established that the amount of leaf area allowed to remain on a particular cutting type directly influences the rapidity and extent of rooting. This, in part, is related to the production of a complex auxin system by buds and young leaves. It is evident that if this root promoting substance is manufactured in the leaf, cuttings will root more readily from leafy rather than from defoliated shoots. It is evident also, that in general, there *is a downward translocation of these substances* after they have been produced.

Further investigations have shown that one of these plant hormones is indoleacetic acid, which is of comparatively widespread occurrence. This chemical has since been synthesized in the laboratory, and as a result of its root promoting properties is used as one of the main constituents in many of our commercial rooting powders.

Methods of Applying Root Inducing Substances

Cuttings of *Acer japonica,* as well as cuttings of the difficult-to-root subjects have been successfully propagated at the Boyce Thompson Institute by the use of lanolin-hormone pastes. Increased rooting response was obtained by the application of the paste to stock plants some 21 days prior to taking the cuttings. The lanolin method for applying root inducing substances has also been reported by Cooper (2). In experiments with lemon cuttings the application of a paste containing indoleacetic acid (one part IAA to two thousand parts lanolin) to the lower epidermis of wounded leaves resulted in an increased rooting response.

From the practical standpoint, however, root inducing substances applied in a talc or bentonite powder has proven to be the most economical method for treating cuttings of ornamental plants. At the Morden Station cuttings are dipped in the acid impregnated bentonite immediately prior to inserting them in the rooting medium. This affords better control over the acid intake in comparison to the less convenient and time consuming dip method of hormone application.

Results of Early Trials Using Root Inducing Substances

Early experimental trials at the Dominion Experiment Station at Morden, Manitoba, with greenwood cuttings re-emphasized the fact that the difference in rooting potential between genera, species, and even between varieties of the same species were marked. Repeated attempts to obtain a satisfactory stand of the American Elm (*Ulmus americana*) from cuttings resulted in failure. It was observed that, in general, the cuttings lost their foliage after a few days in the rooting medium, although occasionally a few cuttings were found to be well calloused. Subsequent experiments using root inducing substances gave a slight increase in the number of cuttings rooted. A further improvement was observed when defoliated cuttings were removed from the medium, and subjected to a second hormone treatment. It was found that by careful selection of cutting material, as well as the application of two chemical treatments at about ten day intervals, stands as high as 40% could be obtained This was significant in that the genus as a whole is particularly difficult to root from cuttings.

Observations over a number of years show that results obtained from using the same formula on identical varieties will not give consistent results. In this connection there is a difference in response by identical varieties from year to year. Varieties of *Syringa vulgaris*, for instance, show a considerable variance in their response to root inducing substances. In extensive trials over a three-year period no correlation between suckering habit and rooting ability of clones of the common lilac could be observed, although the two phenomena were originally believed to be correlated.

Results of Recent Trials Using Root Inducing Substances

Indolebutyric acid, and naphthaleneacetic acid, compounds having similar root inducing properties as indoleacetic acid have been tested singly and in combination at the Morden Station. In addition extensive trials with a number of commercial preparations including Auxilin, Hormodin A, Hortomone A, Indanol, Auxan, and Rootone have been carried on. The preparation known as Auxan has been found to be the most satisfactory commercial form of hormone tested to date. Of eleven of our own rooting preparations, two have given us consistently good results. These preparations contain: (1) one part indoleacetic acid to one thousand parts bentonite, and (2) one-half part each of indoleacetic, indolebutyric, and naphthaleneacetic acid per hundred parts of bentonite.

In this season's trials the usual collection of greenwood cuttings was inserted in sand in the period June 18-20, 1953. All material was treated with the commercial root inducing substance, Auxan, prior to insertion in the medium. The season was considered to be normal; all plant materials were in a satisfactory stage of growth for propagation at the time of sampling. After collection, cool weather conditions prevailed and consequently a minimum of use was made of the portable lath shade system. Leaf spot was somewhat more troublesome than normal and was responsible for defoliation of some varieties prior to rooting; where this was severe the stand of cuttings was considerably reduced. By the end of the season transplanted cuttings had become well established in open frames.

Table 1. Response of Greenwood Cuttings to Auxan Treatment

Plant Name	Percent Rooted Cuttings	Plant Name	Percent Rooted Cuttings
Pachystima canbyi	100	Prunus cistena	33
Rose Harison Yellow	6	Prunus triloba fl. pl.	90
Rose Hansa	70	Potentilla purdomi	100
Rose Blanda Hybrid	48	Potentilla Farreri	86
Philadelphus Snowflake	80	Viburnum carlesi	60
Philadelphus x Silvia	66	Viburnum trilobum	100
Spiraea Vanhouttei	70	Weigela Eva Rathke	100
Spiraea rotundifolia	70	Syringa Rotha magensis	50
Spiraea prunifolia	100	Syringa Nocurne	100
Lonicera spinosa	80	Ulmus pumila	100
Lonicera spinosa alberti	40	Weeping Elm	4
Caragana spinosa	80	Cotoneaster lucida	20
Caragana Chamlagu	100		

Conclusions

As a result of more than ten years work with indoleacetic, indolebutyric and napthaleneacetic acids, used either alone or in combination, in concentrations varying from one half part to one and one half parts per thousand parts of bentonite, one preparation has been consistently outstanding as a root inducing substance for greenwood cuttings. This preparation, referred to as Formula No. 4 is compounded by mixing one part indoleacetic acid with 1000 parts bentonite. While there has been a higher percentage of cuttings rooted in some years, as a result of using one part of naphthaleneacetic acid per one thousand parts of bentonite, this has not been consistent.

REFERENCES CITED

1. BOYSEN-JENSEN, P. 1910. Über die Leitung des phototropischen Reizes in Avenakeimpflanzen. *Ber. Deut. Botan. Ges.* 28: 118-120.
2. COOPER, W. C. 1935. Hormones in relation to root formation on stem cuttings. *Plant Physiol.* 10: 789-794.
3. DARWIN, C and F. DARWIN, 1880. *The power of movement in plants.* London. 592 pp. (Reprinted 1888, New York.)
4. WENT, F. W. 1928. Wuchsstoff und Wachstum. *Rec. Trav. Bot. Neerland.* 25: 1-116.
5. ———. 1938. Specific factors other than auxin affecting growth and root formation. *Plant Physiol.* 13: 55-80.

Dr. Emsweller presented his paper. (Applause)

(Editor's Note: Dr. Emsweller's talk was illustrated with more than fifty slides. His talk, as presented in these Proceedings, has necessarily been edited, but only to the extent necessary to provide continuity in the absence of the illustrative material.)

Recent Advances in Research That May Be Applied to Horticultural Problems

S. L. EMSWELLER
Head, Division of Ornamental Plant Crops and Diseases,
United States Department of Agriculture
Beltsville, Maryland

When one attempts to speak on a subject as broad as indicated by this title he is confronted with the problem of selecting a few items among the many that are available.

Horticulture is a very broad term and one that is difficult to define. To many it concerns all phases of production of horticultural plant materials. In this sense it includes breeding, pathology, physiology, entomology and all the related fields. It is only very recently that a horticulturist was supposed to be informed in all these fields and in fact many amateur gardeners still consider him a source for all information on all sorts of plants.

At the present time research on horticultural plants is being done by many workers who classify themselves as physiologists, geneticists, pathologists, entomologists and cytologists. Modern research is so complex that it is usually impossible for one man to be trained in all the scientific fields that may be utilized in solving any problem. This has led to close cooperation between research workers trained in different fields and most of the recent discoveries in the plant sciences are the result of fine team-work between two or more investigators.

This is the atomic age and in contemplation of the horrible fact that man has learned how to obliterate whole cities at one fell swoop, we lose sight of the tremendous strides that have been made in the same period in the field of plant research.

Tonight it is my privilege to review with you a few of these discoveries that we as plantsmen are vitally interested in, and that are destined to affect our future handling of the plants we grow. Things are happening so fast that most of us are frequently in a state of confusion but I shall try to make this talk as clear as possible and hope that I succeed better than I did on a former occasion when I was giving a series of three lectures to some college sophomores. I was instructed to be factual but non-technical, and the first and second lectures seemed to me to be getting across very well. On the third day, you can imagine my surprise when I saw a young man seated in the front row before me carrying a large card bearing the letters P. A I. K I thought it was some sort of fraternity initiation stunt, but finally my curiosity overcame me and I asked him what P. A. I. K. stood for. He replied, "It means Professor am I confused?". "But", I said to him, "Surely you know that confused is not spelled with a K" He replied, "Professor you don't know just how confused I am".

Among the many revolutionary developments in plant research of the past decade, we find the tremendous forward strides that have been made in controlling insect pests and plant diseases. By now practically everyone is familiar with the aerosol bombs used for controlling insects in greenhouses as well as in our homes. The aerosol method of applying insecticides was developed at Beltsville and a public service patent was issued, so that no one manufacturer could control or monopolize the method. Prior to the development of the aerosol method of dispersal of insecticides it required several hours to efficiently spray a 150 foot greenhouse and the control effected always left something to be desired. The same area of greenhouse space is now treated in about one and one half minutes, and an entire range of a greenhouse can be handled in a relatively few minutes whereas it formerly required an entire day.

It is difficult for us to realize just what has and is happening in the insecticide and fungicide field. Up to now we have tested only a tiny fraction of the various compounds that have potential possibilities. It is also interesting to note that as these new compounds became available, the aerosol method of application also made its appearance. The aerosol application of hexe-ethyl-tetro-phosphate to greenhouse roses meant an increase of almost 100 percent and caused one particular grower to drop plans for a new greenhouse. These results mostly reflect what happened when red spiders were eliminated. The increase of roses during the months of July, August, September, and October were especially spectacular.

A more recent development is concerned with the use of some of the anti-biotics in controlling plant diseases. You are all familiar with the tremendous strides that have been made in combatting human diseases since the anti-biotics have come into use. There are as you know many bacterial diseases of plants and one of these is commonly known as halo-blight of beans. In preliminary tests, the organism was cultured in petri-dishes and after strong growth was established, a small wafer of filter paper impregnated with an anti-biotic was placed in the center of each petri dish. The bacteria were killed as was evidenced by the cleared circle around each wafer of impregnated filter paper. Following these laboratory tests, infected plants in the field were treated with a dust containing an anti-biotic. While practically all the different anti-biotics used killed the bacteria in the petri dishes, they were not all effective when applied to the plants. Such results explain why all scientists are very cautious and insist in thoroughly proving an hypothesis before making a positive statement. Field trials with certain materials have been successful, and these results have greatly stimulated work on other bacterial diseases of plants, and probably opened a new field, the exploration of which may lead to invaluable results.

At Beltsville in the Division of Ornamental Plants and Diseases we are fortunate in having several fellowship grants for students to work on a particular research problem of special interest to the organization granting the funds. The students take their course work at the University of Maryland and carry on their research with us at Beltsville. One of these fellowships was granted by the American Rose Society for research on black spot of roses looking toward eventual breeding for resistance. The first phase of this work has now been completed by Mr. W. R. Jenkins.

Emphasis has been placed on a further study of *Diplocarpon rosae*, the fungus causing black-spot. It was necessary to determine whether all populations of the fungus were the same in their ability to cause the disease, or whether there were different pathogenic races.

First of all it was necessary to find a medium on which the fungus would grow well and produce enough spores to use in inoculation tests. Formerly the disease could be carried only on growing rose plants. Finally a culture medium of canned green pea extract containing one per cent sucrose and two per cent agar was found to be satisfactory for growing the fungus in test tubes. The fungus grew well and produced a plentiful supply of spores for inoculation tests.

A method for artificial inoculation was developed in which detached rose leaflets were inoculated with one drop of a spore suspension. The suspension was obtained by washing a test tube of the fungus growing on green pea-agar. The leaflets were held at 75° F. for eight days, after which they were rated according to the diameter of the black spot lesion. A resistant rose does not show any spotting. This technique now makes it possible to test literally hundreds of plants in a day.

So far twenty rose varieties and species have been used to test the fungus populations that have come from collections of black spotted rose leaves obtained from all over the country. The work to date has shown that pathogenic races of this disease do exist, and this explains why a rose reported to be resistant to black spot in one area is often found infected when planted in another area. This complicates the breeding program, since resistance should be found to all races of the disease before the over-all program can be said to be effective.

It was my good fortune to visit Europe a year ago last September and again the past spring in April. On the first trip I was one of several Americans invited to present papers at the International Horticultural Congress held in London from September 8 to 15, 1952. On this trip it was possible for me to have a few days in Holland, Germany and France.

In April of this year, I was invited to be a member of the International Jury for the International Flower Show, held every ten years in Holland and known as "The Flora". I was in Holland for three weeks during the height of the bulb flowering season, and was also able to visit all the research institutions where work was under way on horticultural plants.

While in Holland I had expected to stay in a hotel in Harlem, but I was met at the Schiphol airport near Amsterdam and driven to Heemstede where Dr. and Mrs. E van Slogteren had decided otherwise and I spent a delightful three weeks as a guest in their home in Heemstede.

I was given a car to use while in Holland and I was able to drive all over this fascinating country and see all the research I was particularly interested in. Most of my time was spent at the Flower Bulb Research Station at Lisse, where Dr. van Slogteren was the Director. This station was established solely for research on flowering bulb diseases, and has done some very fundamental work in this field. The good Doctor is revered by the Dutch bulb growers and his laboratory is located in the heart of the flower bulb district and the research is concerned mostly with daffodils, tulips, hyacinths and Dutch iris.

One of the most interesting of the many programs that Dr. van Slogteren was working on was their very exact method of determining the presence or absence of a virus disease in a plant. This method was first proposed some years ago by Helen Purdy Beal at the Boyce Thompson Institute. It remained dormant until a few years ago when Dr. van Slogteren, seeking a rapid method for determining the presence of plant viruses, decided to explore its possibilities.

The method is based on the fact that when plant juice containing a virus is injected into the blood stream of an animal, the blood of the animal forms anti-bodies to counteract the foreign material. It may require from twelve to fourteen injections of the virus juice into an animal before a sufficient amount of anti-bodies are formed They have found that this depends on the diet fed to the animals. Carbohydrates should be kept low, but proteins should be high to keep the animal from becoming fat.

When blood is removed from an animal it is allowed to stand at room temperature for several hours. If the coagulation settles, the plasma is decanted off, if not the coagulation is punctured with a fine sterile needle and it then settles to the bottom The serum containing the anti-bodies may be stored for years at about 25° to 27° F. The serum may be diluted to as much as 1 part serum to 320 parts .9 per cent NaCl.

Both horses and rabbits are being used for this work. The injections in a horse may remain effective for as long as one and one-half years. The blood stream maintains a supply of anti-bodies during this period with a gradual loss taking place from month to month.

Only a small amount of blood is removed from the rabbit and after the serum is decanted it is taken to a laboratory where one of the technicians has leaves from a known virus plant as well as from the test plant. The juice is pressed from leaves of each and placed on microscope slides. These slides are placed side by side and a drop of the purified and diluted serum is added to each. The reaction is immediate. A clumping of the chloroplasts indicates that the plant is infected with the virus.

At the present time Dr. van Slogteren has developed anti-sera for about twenty plant viruses. The method is, as you have seen, very rapid and they can literally test thousands of plants in a day. Practically all seed potatoes in Holland are now run through these tests before they are certified.

This very rapid method of testing plants for virus is certainly an improvement over the tuber indexing in common use with potatoes. Dr. van Slogteren has developed anti-sera for five different potato viruses, and now furnishes all the potato districts of Holland with enough anti-sera to test all potato plants destined for seed. When a hyacinth, tulip, daffodil, iris, lily, or gladiolus is brought to the laboratory one of Dr. van Slogteren's technicians can tell in a few minutes whether it is healthy or carrying a virus.

In Holland I also visited the famous nursery town of Boskoop and saw all the research work being done there at the Nursery Research Station. This is a most unusual town in that the nurseries are built on small islands surrounded by canals. The land has been built up over the centuries by dredging soil from the bottom of shallow lakes and piling it up.

One interesting thing I saw here was their double glass frames used for rooting cuttings. These frames are about 2-½ to 3 feet deep and the lowest glass sash rests just over the cuttings. The second sash rests at the top of the frame leaving an air space of 12 to 18 inches. These frames are used for propagating many types of plants and especially for handling newly grafted rhododendron. They use *Rhododendron ponticum* seedlings as understocks and approach grafts. This community is practically 100 per cent engaged in the nursery business and on all sides of the highway the small canals and nursery islands extend as far as you can see. At the Felix and Dyphuis nursery they had a large area devoted to layering of magnolias.

At Wageningen University I saw many interesting things including experiments showing the effects of removing the foliage from plants at various stages of growth. One of the most striking and responsive plants was the tomato. Complete defoliation of tomato induced flowering on even very small seedlings, and, of course, this would greatly speed up a breeding program.

Returning now to work nearer home, I want to mention some of the interesting things that are being done with plant hormones, or as we now call them, growth regulators I am sure you are all familiar with the use of these regulators in inducing rooting of plants, and controlling premature fruit dropping. Recently it has been found that these regulators can also aid in overcoming sterility in some plants. Most of the Easter lilies are highly self-incompatible and we have never been able to obtain seed on some when we have used their own pollen. Several years ago we started to explore the effects of using growth regulators at the time of pollination. The regulators were dissolved in lanolin and applied to various parts of the flower just at time of pollination. The most successful method was to make a wound at the base of a petal and apply the lanolin mixture on the injured area. We used a large number of regulators and several were effective, but 1% naphthalene acetamide proved the most effective. In the Easter lily variety, Creole, for example, a flower that was treated produced a large seed pod and some seed, the untreated flower failed to form a pod. Both flowers were pollinated at the same time. This treatment has made it possible for us to obtain several lily hybrids that we have always failed with when the regulator has not been used.

The growth regulator treatment has also proved beneficial in breeding of lima beans. It is very difficult to obtain very many seed from lima bean crosses and most of the flowers drop after they have been pollinated. Bean flowers are very small and the treatment of the lanolin-growth regulator mixture is applied by using a needle to scratch it into a wound at the base of the pistil. Even with crosses that succeeded occasionally without the regulator, the amount of seed obtained was greatly increased when the regulator was used.

While in England last year, I visited the John Innes Horticultural Research Station to see the work they were doing with horticultural plants. I was very happy to learn that they had obtained pear x apple hybrids by using our growth regulator treatment. These are the first known apple x pear hybrids and have been proven to be hybrids following cytological examination. The plants are still very small and it will be interesting to see them when they flower.

Just recently Dr. Rick at the University of California has written me that he has obtained certain species crosses in tomatoes by using growth regulators at time of pollination. It is possible this method may produce some plant hybrids that have hitherto been unobtainable.

While we are discussing plant breeding let us consider for a few moments another phase that appears to hold considerable promise for the future. We all know that the hereditary material of one generation is transmitted to the next by means of chromosomes. There are 24 chromosomes in the garden lily. If you look closely, you can see there are 12 different kinds of chromosomes We say there are 12 pairs of chromosomes, and every living cell making up the lily plant will have 24 chromosomes. Twelve of these, that is one of each pair came from the male gamete, and twelve came from the female. When a plant has two of each type of chromosome present we call it a diploid, the prefix "di" meaning two, or here two of each kind of chromosome. If three of each kind are present it is then called a triploid, if four are present it is a tetroploid, etc

For some years it has been known in rare cases that a diploid plant may produce a tetraploid branch, and such a branch may bear larger flowers. A few years ago it was found that certain drugs could be used to double the chromosome number and make tetraploids at will. Tetraploids have been obtained in the garden lily and there are four of each kind of chromosomes present. These tetraploid lilies are made by immersing lily scales in a colchicine solution for from three to four hours The colchicine enters the base of the scale and is present in the cells when the scales are planted outdoors in rows in early fall. Scales handled in this manner soon start to produce adventitious buds or scale bulblets and a fairly high percentage of the bulblets will be found to be tetraploids. So far we have made all the commercial varieties of Easter lilies into tetraploids, and in most instances the flowers have been larger and of greatly increased substance. The tetraploid lilies have been very self-sterile, but finally we have obtained some seed and the seedlings have been fairly fertile. At present we have a population of several thousand tetraploid seedlings to select from. We have also made tetraploids of snapdragons, carnations, poinsettias and daylilies.

In general tetraploids are more vigorous than diploids and bear larger flowers of much greater substance. Almost without exception, however, they produce fewer flowers per plant and most of them flower later than the diploid. It appears however that selection among tetraploid seedlings can improve the yield and also increase earliness.

In addition to ornamentals, at least one tetraploid apple has been produced by colchicine treatment at Beltsville. One of the advantages of a tetraploid apple will be the possibility of producing triploid apples by crossing the tetraploid with diploids. Many of our best apple varieties are natural triploids and the production of varieties with three sets of chromosomes appears very promising in apple breeding.

Grape breeders also have been very active in making tetraploid grapes. The tetraploid grape breeding program at California and at Beltsville is showing that some very fine new varieties will be developed by inter-pollinations within the artificially induced tetraploids.

Another promising use of induced chromosome doubling is in making sterile hybrids fertile. It is well known that many hybrids that produce no seed become fertile when their chromosome number is doubled.

It has not been long since Garner and Allard demonstrated that flowering of many plants was controlled by the length of day. Plants were roughly classified as short or long day plants depending on whether they flowered on a short or long day. The light need not be from sunshine, but can be from a carbon arc, a fluorescent tube, an ordinary mazda bulb, or from other sources. We have underground rooms at Beltsville where plants can be grown from seed to seed without ever being exposed to any daylight. We also have small outdoor houses equipped with artificial lights and with tracks running into the houses for small cars on which plants in boxes or pots may be grown exposed to sunlight for part of the 24 hour period then rolled into the house and exposed to additional illumination for any desired time. By means of these facilities it is possible to study the effect of varying the amount of both daylight and artificial light and to compare the effect of various types of artificial light.

Sugar beet plants, grown in the winter on a controlled 8 hour daylight day do not flower. Our sugar beet breeders wanted to flower these plants so they could make cross pollinations in the winter and speed up their breeding work. The plants failed to flower. A similar lot of plants was given the same 8 hour day of daylight plus 8 hours of artificial light furnished by daylight fluorescent tubes. These plants also failed to bloom although they were getting practically the same length of illumination they get outdoors in the summer when they do bloom. A third lot of plants was also given an 8 hour daylight day plus 8 hours of artificial light furnished by mazda bulbs. These plants flowered and our plant breeders were able to make their cross-pollinations in the winter and thus speed up their work. We do not know why the plants responded in this way, but the amazing thing is that plants do differentiate between different types of light and respond differently.

Our strawberry breeders also wanted to flower their plants in the winter, but could not get flowers on some varieties they wanted to use in their breeding work. When these plants were grown under Mazda bulbs, they flowered with 11 and 11½ hours of light but failed to bloom with longer periods of illumination.

The effect of light on some plants may not appear until months after the light treatment is applied. In the case of azaleas, the variety Hinodigeri was exposed one year to Mazda light for 9, 12, and 15 and 18 hour periods for 6 weeks. The treatments were applied when flower buds for the next year were being formed. The plants were kept outdoors until cold weather then placed in a greenhouse and forced. Straggly branching growth resulted from the longer exposures to artificial light.

Many plants have been popularly called short-day or long-day plants. This refers to such plants as chrysanthemums that flower in the fall as the days become shorter. Poinsettias also flower at Christmas time because of the short days at that season. We are now, however, calling these plants long night plants. If poinsettias are exposed to short days and long nights they do flower. But if they are exposed to the same short day, and then at midnight are exposed to artificial light for only one minute, they will not flower. The long night then is the important factor.

Recently it has been shown that seeds are very sensitive to the red and infra-red part of the spectrum. There is a stimulating effect of red light and an inhibiting effect of far red light on the germination of lettuce seed and the seed respond to the last light to which they are exposed.

With pepper-grass, a common weed, only one-quarter of a minute of radiation is sufficient to produce some germination and four minutes produced a high germination. All this helps explain why we usually obtain a large number of weed seedlings following cultivation. Stirring up the soil pulls weed seeds up to the surface where they are exposed to light and they then germinate rapidly.

We have recently been doing considerable work on the effect of nutrition on growth and performance of some flowering plants. Flowering bulbs such as daffodils and corms such as gladiolus are excellent to work with because they can be maintained year after year

Let us first look at the work on gladiolus. Results of a 3-year experiment consistently showed that large flowering sized gladiolus when grown on an average garden soil gave better results when no fertilizer was used. In fact, applications of nitrogen produced fewer flowers, *shorter spikes,* and later *blooming.* Very *small corms* and *cormels* did, however, need additional fertility. It must be pointed out that the soil should be a fairly good garden soil. Sandy soils and ones very low in fertility require some fertilizers, but even here applications should be light.

During the course of the fertilizer trials on both gladiolus and narcissus, it was found that certain fertilizers always increased the amount of fusarium rot. On gladiolus the disease is commonly called yellows, and on daffodils it is known as basal rot. In all instances as the amount of nitrogen was increased, the virulence of the disease increased. There were also differences in the effectiveness of various sources of nitrogen in increasing the rots. All forms of organic nitrogen increased the disease more than inorganic or so-called chemical nitrogens. Such results led us to investigate the nutrient requirements of these fusarium diseases. These organisms are themselves small plants and require nutrients just as large plants do. We also have some evidence that high levels of nutrition can increase the virulence of a leaf disease on gladiolus. Heavy applications of nitrogen, phosphorus, and potassium result in an increase of the disease known as curvularia leaf spot. Plants given only water show no disease, those with NPK are lightly infected, but when five times as much NPK was applied the plant was severely infected, and when 25 times as much NPK was used the disease killed the plant. Thus we may eventually be controlling some of our plant diseases by means of better use of fertilizers.

There are many other new developments that I might tell you of, but the hour is late and we have all had three hard days. Perhaps I have tried to cover too much territory in this brief period of time, but I did want you to know that all the startling research is not being done solely by the atomic physicists. What the future holds in plant research is difficult to foretell. We have just begun to open the doors to new fields of work and like treasure hunters, research workers are looking into every corner and every crack to unravel the secrets of Mother Nature.

PRESIDENT CHADWICK: We are all most grateful for the excellent preview of some of the recent developments in horticultural research which will help in the production of horticultural plants. It was very inspiring and we thank you, Dr. Emsweller, very much indeed.

The Third Annual Meeting of the Plant Propagators Society adjourned *sine die.*