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 cuttmgs. *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-