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

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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 in-

vestigators 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 fol-

lowing 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 juni-

pers. 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.

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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 material 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)