THE EFFECT OF THE SYNTHETIC PLANT HORMONES IN THE PROPAGATION OF FOREST TREES

by

LAWRENCE WILLIAM ZACH

A THESIS

submitted to the

OREGON STATE COLLEGE

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1941

APPROVED:

Redacted for privacy

Professor of Forestry In Charge of Major

Head of Department of Forestry

Redacted for privacy

Chairman of School Graduate Committee

Redacted for privacy

Chairman of State College Graduate Council

ACKNOWLEDGEMENTS

The writer wishes at this time to acknowledge the help of the men and institutions whose aid and encouragement made this program possible.

The writer wishes to thank the following men: Professor W. F. McCulloch and Professor T. J. Starker of the School of Forestry Faculty, under whose direction this work was carried out; the following members of the United States Forest Service: Mr. F. D. Hanson, Susanville, California; Mr. J. W. Fox, Haugan, Montana; and Mr. William F. Will, Carson, Washington, all of whom furnished planting materials; Merck and Company, Manufacturing Chemists, who gave information and sources of material; Mr. H. S. Besse, vice director of the U.S.D.A. Experiment Station at Corvallis, who provided greenhouse space for this work; Mr. Verne McDaniel, of the Oregon Forest Nursery, who furnished seed, planting stock, and nursery space for these experiments.

The writer wishes to express his sincere appreciation to these men whose co-operation made this work possible.

CONTENTS

THE EFFECT OF THE SYNTHETIC PLANT HORMONES IN THE PROPAGATION OF FOREST TREES

Introduction

The purpose of this work is to initiate a program of research to work out practical methods of applying plant hormones in the reproduction and establishment of forest trees. The work is being done with cuttings, seedlings, and seeds.

In order to provide background for this work, the work of other investigators of the past few years has been reviewed and analyzed. Much pure research has been carried on in the discovery and development of plant hormones. Some work has been done with the rooting of forest tree cuttings, but, except in a few cases, there has been no attempt to develop methods for large-scale low-cost production of planting stock. With the knowledge and information now at hand it seems that an endeavor should be made to evolve practical methods for the use of these hormones in reproducing forest trees.

Since the growing of trees is a relatively long term project, all the results from this program of research will not be complete for some years. However, preliminary conclusions from this work will be apparent at earlier intervals in the program. Such work as seed treatment will indicate positive or negative results in a short time and indicate the direction of further work along this line.

EARLY WORK WITH PLANT HORMONES

The history of the discovery of plant hormones, their isolation, and early application is beyond the scope of this program. This phase of the plant hormone field has been thoroughly covered in some recent investigations (52). The writer (79) covers the application of this field to forestry and reviews the possibilities in this field.

OBJECTIVES SOUGHT THROUGH EXPERIMENTAL PROGRAM

The objectives sought through this program are as follows:

1. To investigate the possibilities of a vegetative method for reforesting the denuded timber-land of the Northwest. The purpose of this method is to attempt to provide a cheaper, faster, and more certain method of re-establishing forest growth.

2. To further develop practical vegetative methods of reproducing clones of desirable species of forest trees which cannot now be propagated efficiently.

3. To develop the use of plant hormones to increase survival of seedlings in field planting and in nursery transplanting. Preliminary work indicates that the hormones can do this by: (a) stimulating root growth,

(b) increasing the size and quality of the root, (c) reducing root shock in transplanting, and (d) providing a better top-root balance.

4. To develop the use of the plant hormones in growing seedlings in order to: (a) reduce delayed germination, (b) raise the tree percentage, (c) appreciate uniform germination, (d) increase uniform initial growth, and (e) reduce or eliminate damping off damage.

RECENT WORK IN REPRODUCTION OF FOREST TREES BY THE USE OF HORMONES

1. Procedures in the Rooting of Dormant Cuttings of Forest Trees

The past few years have seen great interest and much work in the use of plant hormones on cuttings, seedlings, and seed. Cuttings have been given the greatest attention. A number of species of forest trees have been propagated by rooting cuttings, though in only a very few cases have these experiments resulted in methods adapted to large scale production of forest trees for field planting.

Shipmast locust (Robinia pseudoacacia var. rectissima)

Stoutemyer, et al, (61) developed a method of treating shipmast locust cuttings which allows the reproduction of this desirable clone on a large scale basis. This method is especially useful in view of the fact that the use of shipmast locust in erosion control was limited because of difficulties in reproducing this tree; since the tree bears little or no seed and rooting of stem cuttings was unsuccessful, the only methods of reproduction were by root suckers or by root cuttings. Neither of these methods is adapted to mass production of planting stock.

The method developed by Stoutemyer consists of using hardwood (dormant) cuttings taken in January, February, and March, from growth of the current season from any part of the tree. The cuttings are sectioned, 6 to 8 inches long, 12 mm. or more in diameter, using no apical ends, and no attention is given to the buds in relation to the lower or upper end of the cutting. For ease in handling, the cuttings are bundled in bunches of 25 and are held together with rubber bands.

The new device inaugurated by Stoutemyer is the callusing of the cuttings before treatment with the hormone. He callused cuttings by packing them in wet sphagnum moss wrung out in water, then placing the cuttings in a special tight box. This was kept at a temperature of 68 to 80 degrees F. for about 10 days. He states that cuttings can also be callused by packing them in wet moss in flats which are then placed on top of hot water pipes for 10 days. Some success was also attained by packing cuttings in sand in an unheated nursery storage shed.

Treatments consisted of 100 ppm. (parts per million) of indoleacetic acid, indolebutyric acid, alpha-naphthalene acetic acid, naphthyl propionic acid, and phenylacetic acid. Best results came from indoleacetic acid which rooted 87 to 91.5 per cent; alpha-naphthalene acetic acid gave 66.5 to 78.5 per cent rooting; and indolebutyric acid gave 53 to 78.5 per cent rooting. Stoutemyer reports that for most cuttings indolebutyric acid is most successful. Untreated rootings failed to root more than 0.5 per cent.

The hormones were applied by placing the basal ends of the cuttings in the acid solutions for 20 to 24 hours at room temperatures. After treatment the cuttings were planted in greenhouse benches in a sand medium under the usual greenhouse conditions. Outdoor rooting of cuttings was successful at Beltsville, Maryland, when planted May 1 and May 5. Earlier outdoor planting failed. The author (61) further states that talc as a carrier for the hormones is an effective and simple method of treatment though this method requires high concentrations of the acid.

It was possible to produce field planting stock in one season by these methods.

Monterey pine (*Pinus radiata*)

Jacobs (38) reports that reproducing Monterey pine from cuttings promises to be successful in large scale production of planting stock in Australia. The method is expected to overcome the present objection to poor form in the seedling trees. Since the experiments were carried out in a temperate part of Australia, the method may possibly be applied elsewhere. The climate is roughly comparable to the milder parts of eastern Oregon.

Cuttings are taken from trees 4 to 7 years old, at which age the fast growing Monterey pine is 10 to 40 feet tall. Cuttings are taken from the lower and intermediate branches by pulling off the whorls. The branchlets are trimmed to 7 inch lengths using the apical ends. No needles are stripped from the basal ends of the cuttings since this seems to be detrimental to the cuttings.

Jacobs reports that March to September (winter) is generally favorable for setting cuttings out to root. Cuttings are planted in the nursery in trenches 8 inches deep with rows 9 inches apart and cuttings one inch apart in the row. No shade is given the cuttings. Although hormone treatments give increased rooting and better balanced root systems, the cost is not justified. On a commercial basis it requires 4 manhours per thousand to collect, trim, and plant cuttings. Planting stock is produced in one season.

Norway spruce (*Picea excelsa*)

Deuber and Farrar (13), working with Norway spruce, took cuttings of apical ends of growth of the previous season, from lateral branches not over 10 feet from the ground. The cuttings were two to eight inches in length. The needles were stripped from the lower ends of the cuttings. They found December the best month for taking cuttings when using a greenhouse for propagating. The cuttings were planted in washed sand. The greenhouse temperature ran from 55 to 75 degrees F. Their results showed that the most successful rooting appeared on the untreated controls; indolebutyric acid treatments produced less rooting than the controls, and the amount of rooting decreased as the concentrations increased.

Grace (25) reports that cuttings from the lower branches of Norway spruce show almost twice the percentage of successful rooting as the upper branches. His cuttings were of the same type as those described for Deuber and Farrar (13). Grace also found that treatments of indoleacetic acid in talc dust of 5, 100, and 1000 ppm. either failed to stimulate rooting or even inhibited rooting. In another experiment (19) with treated Norway spruce cuttings, he found an increase of 10 per cent in the number of cuttings rooted when a treatment of 1000 ppm. indolylacetic acid in talc dust was used in conjunction with treatments of cane sugar and ethyl mercuric phosphate as compared to cuttings not treated with indolylacetic acid. A concentration of 5000 ppm. decreased rooting below that of the controls. These cuttings were taken in November.

The dust treatment of hormones in talc consists of dipping the basal ends of the cuttings into water or ethyl alcohol and then immediately dipping the basal ends into the hormone powder. Excess dust is removed by gently tapping the cuttings before planting.

Grace used propagation frames with electric bottom heat cables which kept the rooting media at 72 degrees F.

Eastern white pine (Pinus strobus)

Doran, et al, (14) successfully rooted eastern white pine cuttings taken in November from a 30 year old tree. These cuttings were two to eight inches in length and came from growth of the previous season; the cuttings from the lower part of the tree rooted best. The medium was three parts sand to one of peat and was kept at 68 degrees F. Optimum treatment was with indole-butyric acid 200 ppm. for 5 hours at which treatment 70 per cent of the cuttings rooted.

Thiman and Delisle (71) after experimenting with white pine (Pinus strobus) found that cuttings from mature trees consistently failed but cuttings from young trees, under four years old, rooted rather well even without hormone treatment. They used the standard type of cuttings for conifers taken the middle of the dormant season. They report the optimum hormone treatment to be indole-acetic acid, 200 ppm. applied for a

24 hour period. They used media of sand, sand and peat, and pure peat in boxes with hinged glass covers heated by electric soil cables.

Douglas fir (*Pseudotsuga taxifolia*)

Griffith (28, 29) found Douglas fir to root best under greenhouse conditions when the usual type of cuttings for conifers were taken from December to March. When treated with indolebutyric acid the best rooting of 80 per cent occurred at a concentration of 50 ppm. in water for a 24 hour treatment. These cuttings were from lateral branches of young and vigorous trees. The medium was half sand, half peat. The temperature varied from 64 to 82 degrees F.

Sitka spruce (*Picea sitchensis*)

Griffith (28, 29) rooted Sitka spruce cuttings under the same conditions as those used with Douglas fir. He found indolebutyric acid best at a concentration of 25 ppm. for a 24 hour treatment. From December to March 100 per cent of the cuttings rooted at this concentration.

Northern red oak (*Quercus borealis*)

Thiman and Delisle (71) report a high percentage of rooting from cuttings of red oak taken from young trees and given a 24 hour treatment of indole-acetic acid at a concentration of 400 ppm. in water. The conditions of the experiment were the same as those for white pine conducted by these authors.

Hemlock (*Tsuga canadensis* and *T. heterophylla*)

Thiman and Delisle (71) found themselves unable to root a single cutting of eastern hemlock without hormone treatment, but they did obtain good results with treatments of indole-acetic acid; they do not give the optimum concentration for this species.

The Boyce Thompson Institute failed to root cuttings of the weeping variety of western hemlock (*Tsuga heterophylla var...*) which they received through Professor T. J. Starker of the Oregon State College School of Forestry. The methods and treatments used are not known to the writer. The western weeping hemlock trees are located on Alsea Mountain near Corvallis, Oregon; they are the only known weeping variety of western hemlock.

Yerkes (77) rooted cuttings of eastern hemlock using standard cuttings collected in January and treated with 50 to 100 ppm. of indolebutyric acid for 22 hours.

Western red cedar (*Thuja plicata*)

Glasgow and Clark (18) rooted western red cedar for a silvicultural project at the School of Forestry, Oregon State College in 1936. They used cuttings taken in the winter and treated the cuttings with Auxilin (indolebutyric acid). They used the concentration recommended by the Pennsylvania Chemical Corporation.

Griffith (28) states that western red cedar rooted at almost all treatments of a 24 hour immersion in concentrations of 125 ppm. and less. The usual greenhouse equipment was used and cuttings were the same as other previously described conifer cuttings. Western red cedar appears to root easily; it rooted all during the dormant season about equally well with treatments of indolebutyric acid, indoleacetic acid, and naphthalene-acetic acid.

Yerkes (77) rooted 79 per cent of western red cedar cuttings when they were taken in January and treated with 80 to 100 ppm. of indolebutyric acid for 22 hours.

Northern white cedar (Thuja occidentalis)

Yerkes (77) rooted northern white cedar from cuttings taken in October and treated with 60 to 80 ppm. of indolebutyric acid in water for 20 hours.

Western larch (Larix occidentalis)

Griffith (28) in his experiments with western larch rooted only a few cuttings; these cuttings were handled in the same manner as the rest of his work.

Western dogwood (Cornus nutallii)

Griffith (28) found that western dogwood rooted best directly after the leaves had fallen. He used a treatment of 37.5 ppm. indolebutyric acid for 24 hours, and obtained 20 per cent rooting. He used the standard type of deciduous cuttings.

Cascara (Rhamnus purshiana)

Griffith (28) obtained the best rooting in Cascara with a treatment of 25 ppm. indolebutyric acid for 24 hours. Ninety per cent of cuttings taken in October and November rooted at this concentration. The usual type of cuttings and facilities were used.

Aspen (Populus tremuloides and Populus grandidentata)

Snow (56) reports that trembling and large tooth aspen can be rooted up to at least 65 per cent by 10 ppm. indolebutyric acid in water for 27 hours. The cuttings were of the usual type but were taken just before the buds burst in the spring.

2. Procedures in Rooting Some Greenwood Cuttings of Forest Trees

According to present indications softwood or greenwood cuttings taken during the growing season will never be a practicable means of reproducing forests. The growing material is too soft and delicate and requires such exacting conditions that it can not be handled economically.

Afanasiev (2) was successful in rooting grey birch (Betula populifolia), white birch (Betula papyrifera), red maple (Acer rubrum), and white hybrid poplar (Populus alba X p. nivea). He failed to root successfully hard maple (Acer saccharum), and aspen (Populus tremuloides). Cuttings were taken in July and August. Shading was necessary to prevent desiccation. Treatments ran from 5 to 20 ppm. for 6 to 24 hour treatments.

Since softwood cuttings are so delicate, care must be exercised in keeping the humidity high, the temperature high but not excessive, the medium wet, and the cuttings shaded. These limitations call for greenhouse facilities which are too costly to permit the use of this method in reproducing forest trees.

Snow (58) was able to root softwood cuttings of white pine (Pinus stocbus) when he took the cuttings in July and August from trees not over 15 years old. The cuttings were taken from the lower lateral branches and were the standard type of apical ends. The cuttings did not root until the summer following the season in which they were taken. Optimum treatment consisted of indolebutyric acid at 25 ppm. for 6 hours. He used an outdoor sash-covered propagating frame containing decomposed horse manure under a 6-inch layer of a sand and peat mixture.

3. Methods of Treatment

The treatment of cuttings with hormones by propagators of forest trees has been essentially an adaptation of the practices followed by propagators among the horticulturalists. The chief methods are: (a) liquid immersion method, (b) powder treatment, and (c) concentrated liquid dip method.

(a) Liquid immersion treatment:

Except for the earliest experimental method of applying the hormones in lanolin (sheep wool fat) the immersion method is the oldest and most common method of hormone treatment. The method consists of placing the basal ends of the cuttings in the hormone-water solutions for various periods, depending on the kind of cutting and the concentration of the hormone.

Hitchcock and Zimmerman (34) of the Boyce Thompson Institute state that one to eighty ppm. of indolebutyric acid, indoleacetic acid, and naphthalene-acetic acid are most generally used for rooting cuttings. The time will vary from 5 to 24 hours for most forest species. They also make the statement that lower concentrations over longer periods of treatment are less likely to damage the cuttings than high concentrations used for a short period of time (36).

In applying the method of liquid immersion to forest tree propagation by cuttings, investigators in most cases have found it necessary to use rather high concentrations of hormones as compared to concentrations for other plants. The 24 hour treatment is now quite standard in this method of tree propagation. Black locust (61) is treated for 24 hours at 100 ppm. White pine, according to Doran, et al, (14) roots best when treated at 200 ppm. for 6 hours while Thiman and Delisle

(71) recommend 200 ppm. for 24 hours for this same species. These same investigators (71) report a successful treatment on red oak of 400 ppm. for 24 hours. On the other hand there are reports from other investigators such as Griffith (28) who used concentrations ranging from 25 ppm. to 125 ppm. with the majority ranging from 25 to 50 ppm. McCulloch (43) found 8 ppm. to be optimum for Douglas fir at a 24 hour treatment.

(b) Powder treatment:

Following the use of liquid immersion as a treatment powdered talc was employed as a carrier of plant hormones. This greatly simplified the treating process. The advantages according to Stoutemyer (63) are: low cost, saving of time, no loss of time between initiation of treatment and planting, no necessity for concentration charts, and safety of the treatment in the hands of an inexperienced man. He states that the chief objection is the difficulty encountered in using different concentrations. He thinks a concentration of 1000 ppm. should be most generally useful. At the present time the Merck Chemical Company, Rahway, New Jersey, distribute three concentrations of hormone powder known as Hormodin Powder #1, Hormodin Powder #2, and Hormodin Powder #3. [1]

[1] The concentrations of these powders are trade secrets of the Merck Chemical Company. The concentrations in ppm. of these commercial products may be obtained from the Librarian of the School of Forestry, Oregon State College, for research purposes only.

They publish a list of plants whose cuttings respond to these concentrations. Hitchcock and Zimmerman (34) state that powder concentrations may run from 0.5 to 50 mg. per gram of acid to talc; this is a concentration of 500 to 50,000 ppm.

One item of importance in connection with the powder treatment is that the basal portion of the cuttings must be moistened in water or ethyl alcohol, 45 to 90 per cent, or the powder will be ineffective. Kirkpatrick (39) emphasizes the need of wetting the cuttings with water. Hitchcock and Zimmerman (34) report that premoistening with a 50 to 95 per cent ethyl alcohol solution is more effective than water, but that water is more effective than no premoistening. Meahl (45) reports that if cuttings are not dipped in water or alcohol before receiving the powder treatment the hormone will have no effect. Merck and Company recommend dipping the basal ends of the cuttings in water before treating.

Information on results obtained in treating forest tree cuttings with the dust treatments is still indefinite.

(c) Concentrated liquid dip method:

This method consists of dipping the basal ends of the cuttings into a concentrated solution of the hormone. According to Hitchcock and Zimmerman (34) the range will be from one to twenty mg. per gram of liquid; this is a concentration of 1000 to 20,000 ppm. This method has the same advantages as the powder treatment except that it is not foolproof and it is more expensive. Hitchcock and Zimmerman (34) report the powder and concentrated dip methods to be about equally effective. As in the case of powder treatment, the concentrated dip method has little available information on results obtained in using this method on forest tree cuttings.

(d) Other methods of hormone application:

The method of applying hormones in lanolin is still used and this product is on the market. 1/ Recent available reports contain little or no information on the use of lanolin and hormones.

Another method of applying hormones is by watering the cuttings with dilute hormone solutions. Apparently it is rather difficult to control the treatments in this method so investigators are not working with this method at the present time.

The idea has occurred to some investigators that combinations of hormones might prove more effective than application of a single hormone. Hitchcock and Zimmerman (35) combined hormones and found that when they used mixtures of equal activity in any proportions there was little change in activity; when mixtures of substances

1/ General Biological Supply Company Incorporated, Chicago, Illinois.

of unequal activities were used, varied results were obtained which sometimes gave greater than additive effects; neither rooted or unrooted cuttings were benefited by treatment with Vitamin B_1.

Another idea in treating cuttings was to retreat the cuttings at subsequent intervals after the initial treatment. Cooper and Went (9) increased rooting of white pine (*Pinus strobus*) from 4 to 9 per cent by retreating the cuttings three days after the original treatment. For practical purposes both the original and retreatment were failures.

4. Media Used for Cuttings

Sand was the standard rooting medium for a long time. In more recent years the addition of peat moss to the sand is favored by most propagators of cuttings. Hitchcock (33) after rather exhaustive studies states that 90 out of 96 varieties of cuttings rooted best in a mixture of sand and peat. Deuber and Farrar (13) used straight sand. Griffith (28, 29) used equal parts sand and peat moss. Durus (15) recommends one part peat moss to three parts sand. McCulloch (43) used equal parts peat moss and sand. Kirkpatrick (39) says a sand and peat mixture is best. Thiman and Delisle (71) used sand, sand and peat, and pure peat, and secured rooting in each of these media. They recommend sand and peat as being a little better than sand alone. Doran, et al, (14) used three parts sand to one of peat. Pearce (49), working with fruit tree cuttings, used pure sand. Watkins (73), working with tropical plants, used two parts sand to one of peat.

Snow (59) suggests that a medium may be more effective for rooting cuttings if it has become infected with certain species of fungi. He suggests that the cuttings may benefit from the auxins produced by certain fungi. Snow further suggests that fungi harmful to the cuttings might also be present. The writer (79) experienced a loss of the majority of the cuttings of white pine (Pinus monticola) planted in a medium which had been used for rooting cuttings previously; insect organisms served to be the chief cause of loss.

5. Temperatures

The temperature at which cuttings are kept while being rooted is important. Yerkes (77) recommends that the rooting medium be 5 to 10 degrees warmer than the surrounding air. Duruz (15) recommends a bottom heat of 60 degrees F. with the air temperature at 5 to 10 degrees lower. Deuber and Farrar (13) used a temperature of 55 to 75 degrees F. with the medium temperature a little higher. Griffith (28, 29) used an air temperature of 64 to 82 degrees F. and a medium temperature about

4 degrees lower. Grace (19) kept the media at 72 degrees F. and the air temperature at 65 degrees. Kirkpatrick (39) recommends a temperature of 75 to 80 degrees F.; he adds that there is no gain in using hormones if cuttings are stored or planted at low temperatures, since the lower the temperature the less activity the hormones show; after a period of cold the hormone becomes inactivated and does not resume activity even when conditions become warmer. Thiman and Delisle (71) state that bottom heat for pine cuttings is definitely undesirable. In heated boxes the temperature was 75 degrees F. while in unheated boxes it was 64 degrees. Doran, et al, (14) rooted white pine (Pinus strobus) at 70 degrees F. without bottom heat. Chadwick (7) tried bottom heats of 70 to 75 degrees as compared to 80 to 85 degrees F.; he found the high bottom heat undesirable. Pearse (49) recommends a bottom heat of 65 to 75 degrees F.

WORK ON THE STIMULATION OF ROOT GROWTH WITH HORMONES AND VITAMIN B

Work with Hormones

The use of plant hormones in stimulating root growth on seedling or rooted forest trees is just beginning. At this time it is not possible to predict how practicable the hormones will be for that purpose.

Plank (51) in a recent article reported positive results from soaking the roots of slash pine (*Pinus caribaea*) seedlings in 4 concentrations of indolebutyric acid, viz., 10, 20, 40, and 80 ppm. This treatment was for a period of 24 hours. He set these seedlings out under field planting conditions in January and lifted and examined them one year later. He found the 10 ppm. concentration best, giving 90 per cent survival and 80 per cent of these plants had good roots as compared to the untreated controls with 70 per cent survival and 30 per cent good roots. He reports the higher hormone concentrations as having a toxic effect.

Smith and Romberg (55) worked out a system of treating pecan seedlings in establishing orchards to overcome the high seedling mortality. Their best results came from inserting toothpicks soaked in an indolebutyric acid solution into 7/64 inch holes drilled into the roots of the seedlings. The concentration was varied as desired though the authors do not state what the concentrations were.

Swartley (66), working with such trees as horticultural varieties of Picea pungens, Juniperus chiensis, Lonicera spp., and Malus siebaldi worked out a successful procedure of hormone treatment for transplants. His method consisted of using indolebutyric acid in talc dust and Transplantone.1/ The indolebutyric acid was used at a concentration of one to 5000, or the equivalent of 200 ppm. Application was made by putting a quantity of the dust into a paper bag, inserting the roots of a bunch of seedlings, and shaking the inclosed powder and roots vigorously to distribute the dust. The seedlings were then planted. Swartley reports that treated plants produced nearly twice the growth of controls. Treated transplant stock produced well clustered roots while the controls or the Vitamin B treated seedlings did not produce clustered roots. Swartley reports that treatments with water solutions are less convenient and give less marked results.

Swingle (68) reports that some work has been done with Ulmus, Thuja, Picea, Pinus, Acer, Quercus, Malus, and Prunus seedlings by soaking the roots in solutions of indolebutyric acid, indoleacetic acid, indolepropionic acid, and phenylacetic acid at concentrations of 10 to

1/ Transplantone is a commercial hormone product.

40 ppm. The roots were soaked in these solutions for from one to two days just before planting. He reports that there was a considerable increase in root development especially with indolebutyric acid. He adds that experiments are not yet conclusive.

Swingle (68) further reports work done by Chadwick on _Viburnum_ and _Cotoneaster_ (shrubs) where the roots of these shrubs were soaked in solutions of indoleacetic acid, indolebutyric acid, and phenylacetic acid solutions of 10, 20, and 50 ppm. for 12 hours. He obtained definite root stimulation.

Grace (20) gives the hormone treatment of growing plants as an application of .01 to .1 ppm. in watering. He reports that stimulation falls off as plants get older and also as humus content of soil increases. Another method of application is to spray the solution on the plants and then wash it down in watering.

Lindquist (41) took sterilized nutrient solutions derived from cultures of excretions from mycelia of several common mycorrhiza-forming fungi of northern Sweden. He tested these solutions on seedling trees under laboratory conditions. Results were uniformly favorable for some solutions and uniformly detrimental for others. Lindquist suggests that these effects may be due to the hormone action of these fungi excretions. He further suggests the possibility that this phenomenon may explain the whole complex of mycorrhiza relationships.

Work With Vitamin B Factors

The Vitamin B factors are now recognized as the plant regulators which are necessary for root growth and elongation but which do not induce root initials. Turtox News (4) makes the following statement: "Vitamin B_1 is not a root-forming hormone--it is a factor which stimulates a plant to a more rapid growth."

The Vitamin B factors became prominent a few years back when such amazing stories appeared as those by Logan (42) and Adams (1). Apparently the Vitamin B factors are indispensable for root growth, but normally the plant produces sufficient of this regulator without requiring artificial application. The most startling results occurred in sandy soils poor in humus such as some of the California sands. Since practically no work has been done with the Vitamin B factors on forest tree species it will be necessary to review some of the results obtained by horticulturists and gardeners in the use of these substances.

Swartley (66) reports the use of nicotinic acid (a Vitamin B factor) at a concentration of 4 ppm. in water and Transplantone at a concentration of two ppm. in water on such plants as Lonicera, Malus, and Juniperus without marked results.

Stoutemyer (63) reports the use of Vitamin B_6 as a subsequent treatment in rooting cuttings. He says it is a root elongation factor which aids in retaining the leaves of soft wood cuttings for long periods of time. Application consists of one part B_6 to one to five million parts of water; this is two tenths to one ppm. Results are not conclusive.

Went, et al, (76) report doubling the number of roots on lemon cuttings by a treatment of Vitamin B_1 at one ppm. in a 24 hour immersion treatment 7 days after the initial treatment with indoleacetic acid at 200 ppm. Camellia cuttings so treated showed results even more striking; the controls produced a total of 6 roots while the B_1 treated sample produced a total of 67 roots.

Bonner (5) reports an increase in the general vigor of plants of mustard and cosmos when Vitamin B_6 and nicotinic acid were added in addition to Vitamin B_1.

Bonner (6) reports that Vitamin B_1 added to various species in sand culture increased growth in slow growing species but had no apparent effect on fast growing plants.

Chadwick (7) treated <u>Juniperus</u> and <u>Taxus</u> cuttings with commercial hormones; then 12 days later they were watered with a Vitamin B_1 solution of one ppm. This addition of B_1 increased the rate of rooting significantly and apparently rendered the stronger treatments of hormones less toxic. He adds that the B_1 had no effect unless cuttings had been previously treated with the root-inducing hormone.

Pearce (49), working with fruit tree cuttings, found that subsequent treatment with Vitamin B_1, one ppm., did not increase the number of cuttings rooting but cuttings so treated grew more vigorously after removal from the frames.

Turtox News (4) recommends treating transplants with Vitamin B_1 and then watering plants once a week with B_1.

THE USE OF HORMONES AND VITAMIN B ON SEED

The use of hormones and Vitamin B in seed treatment is yet too new to provide conclusive results. In some trials very remarkable results have followed the treatment of seed while in others the apparent results were negative. Little information is yet available on results obtained by treating tree seeds.

Gruenhagen (31) conducted some experiments on red pine (Pinus resinosa) and white pine (Pinus strobus) seed using naphthalene-propionic acid and indol-3-acetic acid to test the effectiveness of these hormones for increasing the percentage of germination and for protecting seeds from soil-borne infections. The naphthalene-propionic acid was used at a concentration of 1000 ppm. in powdered talc while the indol-3-acetic acid was used at a series of concentration from 50 to 2000 ppm. In another set of experiments he used indol-3-acetic acid in a water solution with a 12 hour treatment at concentrations of 50 to 2000 ppm. The experiments were conducted under laboratory conditions. Gruenhagen makes the following statement concerning results: "In summary, these experiments indicate that the 'hormones' used do not protect white and red pine seed from damping off, and do not stimulate the percentage of germination."

In order to provide a background to initiate treatment with tree seed, some of the results obtained by horticulturists and agriculturalists will be reviewed.

Nicholson (48) reports that at the Morris Arboretum of the University of Pennsylvania a dust treatment of lawn grass seed with plant hormones at a concentration of 10 ppm. resulted in a yield of almost twice that of untreated seed.

Welmer (74) reports that soaking of various seed from Gramineae to Compositae in indolebutyric acid solutions of 1:800,000; 1:400,000; 1:100,000; and 1:25,000 was all detrimental. The lower the concentration the less harm resulted. She further pointed out that the roots of beans treated with auxins or hormones developed roots resembling the roots of certain bog plants and muck plants, indicating a possible condition of hyperauxony.

Chadwick (8) treated seeds of various kinds with a mixture of indoleacetic acid, thiourea, and fine talc. In a second mixture he substituted naphthylacetamide for the indoleacetic acid. The concentration was 500 ppm. The dust was applied by shaking the seed and dust together in a test tube. Some seed showed marked response, others showed negative results, and some showed no response.

Flory (17) reports that a Russian scientist obtained an increase in the yield of oats following the soaking of the seed in auxin solution before planting.

Grace (21) gives results of an interesting experiment wherein the damage resulting from the treatment for smuts by formaldehyde, copper sulphate, and mercuric chloride on common seeds was greatly reduced or entirely prevented by adding .01 to 10 ppm. of the phytohormones to the treating solution. He adds that Vitamin B_1 also was effective. From another set of experiments Grace (20) reports: "Treating seeds with hormones incorporated in absorbent dust stimulated both root and top growth markedly, with less danger of overdosage than in the solution treatment." He further comments on the reports of other investigators telling of the inhibitive effects from seed treatment; he thinks this is due to overdosage. He used one-half ounce of dust to a bushel of seed of a two ppm. indolebutyric acid dust. The result was that in 14 days wheat roots from treated seed showed a 55 to 102 per cent increase over roots from untreated seed.

Tang (60) reports that seeds of mustard, tomatoes, and rice were treated in water solutions for 24 hours of 1, 10, and 100 ppm. of indole-3-acetic acid. The plants from treated seed came into flower three to seven days earlier than plants from untreated seed.

Croxall and Ogilvie (10) treated pea seeds with mercurical and cuprous oxide containing from 5 to 20 ppm. of several hormones. Yield from treated seed produced a yield up to 80 per cent greater than untreated seed.

SUMMARY OF PROCEDURES USED BY PROPAGATORS

Conifer Cuttings

1. In general cuttings from young trees root much more consistently than cuttings from older trees.
2. Cuttings from the apical ends of lateral branches root much better than terminal cuttings.
3. Cuttings from the lower part of the tree are superior to cuttings from the upper portion of the tree.
4. Propagators in general prefer cuttings of from three to eight inches in length.
5. Cuttings should always be growth of the current season and be of vigorous healthy growth.
6. The best time to take conifer cuttings is from December to March.
7. Practically all investigators strip the foliage from the basal end of the cuttings. According to Jacobs (38) this practice does more harm than good.

Deciduous cuttings

1. In general the age of the tree seems to have little effect on the rooting capacity of the cuttings provided the cuttings are from vigorous, thrifty wood.
2. The best cuttings are from sections of shoots of the current year from any part of the tree.
3. The inclusion of heels (union of new to old wood)

is generally found undesirable.

4. Some deciduous cuttings require a callusing treatment before successful rooting can take place. The callusing may be carried out by placing the cuttings in wet moss and packing them into flats. The flats are then placed on t op of the hot water heating pipes in the greenhouse for a week or ten days before treating and planting. The temperature should be around 70 degrees F.

5. Cuttings of 4 to 8 inches are usually the most convenient.

Media for planting cuttings

Clean, sharp sand and peat moss is the most popular rooting medium. A mix of one part of peat to two or three parts sand is in common use.

Temperatures

1. Temperatures of 60 to 80 degrees F. are recommended. The range of 68 to 75 degrees F. is probably the most common.

2. Bottom heat of 5 to 10 degrees higher than the air temperature is generally considered desirable.

3 In rooting white pine (<u>Pinus strobus</u>) bottom heat has been found to be detrimental.

Moisture

1. Frequent light waterings are recommended over occasional heavy ones.
2. Atmospheric humidity should be high to prevent the rootless cuttings from drying out.
3. At no time in the taking, treating, and plantings of cuttings should the cuttings be allowed to dry out.

Treatments

1. The most common hormones are indolebutyric acid, indoleacetic acid, and naphthaleneacetic acid.
2. Indolebutyric acid is the best root-inducing substance for 80 per cent of the plants.
3. The three common methods of hormone application to cuttings are:
   a. Liquid immersion method consisting of a water solution of the hormone varying in concentration from 25 to 400 ppm. The basal ends of cuttings are stood in these solutions for a period of time; 24 hours is the most common length of treatment.
   b. Powder treatment consisting of concentrations of hormones in powdered talc ranging from 500 to 80,000 ppm. The basal ends of the cuttings

are dipped into water or ethyl alcohol and then dipped into the powder. The most effective concentrations have not yet been worked out conclusively.

c. The concentrated dip method consists of just dipping the basal ends of the cuttings into a concentrated solution of 1000 to 20,000 ppm. of the hormone in water. Effective concentrations for different plants have not yet been worked out conclusively.

4. Low temperatures cause the hormones to become inactive. They do not become reactivated with a subsequent increase in temperature. The decrease in activity due to temperature is a gradual one.

Seedlings

1. Two common methods of application are in use: (a) soaking the roots in a water solution and (b) adding hormones to a talc carrier and applying the powder.
2. The liquid soaking method uses concentrations of 10 to 80 ppm. Inhibitive effects have resulted from using 80 ppm. for 24 hours.
3. The powder treatment promises to be the easiest and most successful. The concentrations range up to 200 ppm. One method of application is the insertion of the plants into a bag containing hormone powder

and shaking the sack to distribute the powder.

4. Indolebutyric acid seems to be the most promising hormone.

5. The Vitamin B factors have a marked effect in root stimulation when applied in watering in concentrations of around one ppm.

Seeds

1. The dust treatment seems to offer the safest and most convenient method of hormone application to seeds.

2. Little information is yet available on treatment of forest tree seeds with hormones.

3. The liquid soaking treatment has shown largely negative results.

4. Concentrations for the dust treatment range from .01 to 500 ppm. This upper limit may be well above safe treating range. Very small concentrations seem to give the best results.

5. Concentrations for the liquid treatment vary from .01 to 100 ppm. The upper limit is probably toxic for most plants. Information is still too inadequate to draw definite conclusions.

6. Some advantage appears in combining hormone treatment with disease control treatments since the hor-

mones prevent injury to the seed from the fungicide.

7. Indolebutyric acid seems to give the most positive results.

GENERAL INFORMATION FOR PROPAGATORS

The standard method of stating concentrations of hormones and Vitamins in this work is in ppm. (parts per million). The commercial products all use their own system of naming concentrations. In the experimental work to follow, the writer is using the hormone products of the Merck Chemical Company, Rahway, New Jersey, who manufacture and market a line of indolebutyric acid preparations under the name of Hormodin. Their Hormodin A is the liquid preparation, and the concentrations on their chart are stated as B. T. I. units; this B. T. I. stands for the Boyce Thompson Institute which helped develop these preparations.1/

The Hormodin Powders #1, 2, and 3 are three concentrations of indolebutyric acid in powdered talc.2/ The Hormodin #1 is meant for use on softwood, easily rooted material. Hormodin #2 is for use on plants moderately difficult to root. Hormodin #3 is meant for use in rooting the most difficult class of plants (mostly conifers).

1/ and 2/ Information giving these commercial concentrations in ppm. is available for research purposes from the Librarian of the School of Forestry, Oregon State College.

The product is yet too new to decide whether it will be successful for many of the forest tree cuttings.

The Merck Chemical Company products are based on much research and testing, including work done by the Boyce Thompson Institute of Plant Research, Yonkers, New York.

The Vitamin B Factors product to be used in experiments to follow is a product of the Galen Manufacturing Company of Berkeley, California. Rather surprising results have occurred in many cases from the use of Vitamin B factors on plants. The concentrations to be used, as expressed in the experimental design following, are as recommended by this Company.1/

Strong concentrations of hormone may inhibit bud development. In some cases this has been so marked as to make optimum concentrations of hormone for root development impracticable; this difficulty is reported by Thiman and Delisle (66) for *Picea pungens* and *Populus spp.* at a concentration of 100 ppm.

1/ The active ingredients and their concentrations are a trade secret of the Galen Company. This information may be obtained for research purposes from the Librarian of the School of Forestry, Oregon State College.

EXPERIMENTAL DESIGN AND PROCEDURE

The following outline is the working plan being followed in a program of experimental work in the use of plant hormones on cuttings, seeds, and seedlings in propagating forest trees artificially. The chief objective is to put the plant hormones to practical use in solving some of the difficulties in forest tree propagation.

EXPERIMENTAL PROCEDURE

The following experiments are being conducted to achieve the objectives of this program:

I. EXPERIMENTS WITH CUTTINGS

Types of cuttings:

Cuttings were made in November, January, and March, from growth of the previous season. All cuttings from coniferous trees were taken from the ends of lateral branches of young trees. No terminal leaders of trees were used since some investigators (24, 76) have found terminal leaders very poor material for cuttings. Hardwood cuttings were sections cut from shoots of the previous season. Cuttings were four to eight inches in length. No heels were taken at the base of the cuttings (a heel is a small section of wood at the base of the cutting older than growth of the previous season). An ordinary 45 degree angle cut was made at the base. Foliage was removed from the lower two inches of the basal end of the cuttings. Cuttings were kept as fresh as possible by packing in wet moss and planting in nursery flats as soon as possible after taking. Hardwood (deciduous) cuttings were taken only in January since the buds were bursting in March. These hardwood cuttings were sections of shoots from growth of the previous season four to eight inches long. The ends of the whips were not used for cuttings. Cuttings were taken from young trees not over 10 years old.

Source of cuttings:

The Douglas-fir (Pseudotsuga taxifolia) cuttings came from young trees on the Peavy Arboretum which is 8 miles north of Corvallis. Western white pine (Pinus monticola) came from the wild stock near the summit of the road between Valsetz and Falls City, Oregon, for the November planting; for the January and March planting, western white pine cuttings were taken from seedling stock from the Wind River Nursery at Carson, Washington, on the Columbia National Forest. Results between the cuttings of the wild stock and cuttings from the nursery stock should not be compared since the conditions under which they are grown differ greatly. Port Orford White-cedar (*Chamaecyparis lawsoniana*) cuttings were taken from the seedling stocks in the Oregon Forest Nursery north of Corvallis, Oregon. Shipmast locust (*Robinia pseudo-acacia erectissima*) cuttings were taken from trees on Professor Starker's property just outside the city limits of Corvallis, on the Oak Creek road. Red alder (*Alnus rubra*) was taken from wild stock along Mary's River near Corvallis. Western hemlock (*Tsuga heterophylla*) cuttings were from two weeping hemlock trees on Alsea Mountain. Professor T. J. Starker has the maps, description, and data on these trees and their location.

Rooting medium:

The rooting medium consisted of two parts of sifted Santiam River sand by volume to one part Canadian peat moss by volume. The peat moss was the fine horticultural grade. The sand was fresh from the river and sifted. The medium was packed solidly into the flats.

Greenhouse space and flats:

House space was secured through the cooperation of Professor R. E. Stephenson, chairman of the greenhouse committee, and Professor R. S. Besse, Vice Director of the Agricultural Experiment Station. The temperature ran from 60 to 75 degrees F. except for the periods of warm weather in March and April when temperatures rose to 80 degrees. Heat was supplied by hot water pipes running beneath the benches.

The greenhouse flats were of new lumber; they were 15 inches wide, 24 inches long, and three and one-half inches deep. The bottom boards were spaced slightly apart to allow proper drainage. Each flat contains 90 cuttings.

Treatments:

1. Powder treatment:

Powder treatments were of three strengths or concentrations of indolebutyric acid in powdered talc. The concentrations were 1000 ppm., 3000 ppm., and 8000 ppm. (parts per million of indolebutyric acid in talc). The active ingredient was indolebutyric acid. The inert ingredient was the very finely powdered talc.

The treatments were applied by first dipping the basal ends of the cuttings into a 50% solution of ethyl alcohol and water; this is important since the liquid is the solvent for the acid in the treatment, and the acid must be in solution to be absorbed by the cuttings. The basal ends of the cuttings were then dipped into the hormodin powders after shaking the cuttings to remove the excess moisture; the excess powder was removed by tapping the ends of the cuttings against the container. The cuttings were then planted upright in the flats by inserting the cuttings two to three inches into the medium depending on the length of the cuttings. The medium was pressed firmly around the cuttings.

2. Liquid treatment:

Liquid treatments were made with solutions of Hormodin A, a Merck Chemical Company product, which is a concentrated solution of indolebutyric acid in ethyl alcohol.

The liquid treatments used were of three concentrations for Douglas-fir, 40, 80, and 160 ppm.; for Western white pine four concentrations were used of 40, 80, 160, and 200 ppm.; western hemlock at 20, 40, 80, and 160 ppm.; Port Orford White-cedar at 20, 40, 80, and 160 ppm.; shipmast locust at 80 and 160 ppm.; and red alder at 20, 40, 80 and 160 ppm.

The commercial Hormodin A concentrated liquid hormone is put out with a chart and graduate for mixing the hormone at recommended concentrations for a number of plants. The concentrations are given as "B.T.I. units."

The treatment was applied by placing the basal ends of the cuttings in one to one and one-half inches of the given concentrations for 24 hours.

The treatments were carried out with lukewarm tap-water in a temperature of 70 to 75 degrees F. Immediately after the treatment the cuttings were inserted in a rooting medium in the same manner as the powder treatments.

The mixing of the liquid treatment was done with an ordinary glass measuring cup and the glass graduate furnished with the Hormodin A concentrate. The basal ends of the cuttings were soaked in glass tumblers containing the hormone preparation.

A special treatment of shipmast locust is necessary before treatment can be given successfully. Black locust will not root without a special callusing treatment. This was done by packing the cuttings in wet moss and placing them in flats on top of the greenhouse heating pipes for 10 days. After this special treatment the usual hormone treatments were applied. The red alder was treated in the same manner. Duplicate sets of locust and red alder were made; half of each set of cuttings was given the special callusing treatment; the other half was given only the hormone treatments.

3. Vita Flor treatment:

One-half of the November cuttings were given a treatment of Vita Flor at the rate of two drops to a gallon of water. The flats receiving this treatment were given one quart to a flat at weekly intervals beginning two weeks after setting the cuttings out and continuing to the middle of March.

Vita Flor is the trade name of a concentrated solution of Vitamin B factors manufactured by the Galen Company Incorporated of Berkeley, California. It is distributed by the Portland Seed Company.

Disposition of rooted cuttings:

All the treated cuttings of Port Orford White-cedar planted in November were well rooted by March. One-half of these cuttings were planted directly in the field on March 11. The other half of these rooted cuttings were planted in the nursery of the Hall Floral Company at Albany, Oregon. Cuttings which are well rooted by May 15 will be planted in the experimental bed of the Oregon Forest Nursery at that time. Cuttings not rooted by this time will be kept in the flats until October when they will be planted in the Oregon Forest Nursery. In all cases the plants will be adequately marked as to time of planting and treatment given.

The cuttings transplanted to the nurseries are to be left in the transplant beds for one or two years, depending on their growth. After this period they will be planted in the field on a favorable site together with proper controls grown from seed. Complete marking of age, season of making the cutting, treatment given, and any other pertinent data will be included on permanent records tied in to properly placed markers in the field planting.

Examination and measurement of results in the transplants and field plantings will recognize the following points:

a. Survival of stock from cuttings as compared to survival of seedlings under the same conditions.

b. Effect of different treatments and different concentrations of treatments in survival.

c. Effect of different treatments and concentrations of treatments on leader growth and general vigor as compared to seedling stock.

d. Time required to grow rooted cuttings to a size suitable for field planting as compared to time required to grow comparable seedling stock.

Cuttings planted--species, time, treatment, and number

Douglas-fir:

Time of Planting	Treatment		Number of Cuttings
November	Hormodin powder	1000 ppm.	20
"	" "	3000 ppm.	20
"	" "	8000 ppm.	20
"	Hormodin A	40 ppm.	20
"	" "	80 ppm.	20
"	" "	160 ppm.	20
"	Checks		10
January	Hormodin powder	1000 ppm.	10
"	" "	3000 ppm.	10
"	" "	8000 ppm.	10
"	Hormodin A	40 ppm.	10
"	" "	80 ppm.	10
"	" "	160 ppm.	10
"	Checks		10
March	Hormodin powder	1000 ppm.	10
"	" "	3000 ppm.	10
"	" "	8000 ppm.	10
"	Checks		10
		total	240

Port Orford White-cedar:

November	Hormodin powder	1000 ppm.	20
"	" "	3000 ppm.	20
"	" "	8000 ppm.	20
"	Hormodin A	20 ppm.	20
"	" "	40 ppm.	20
"	" "	80 ppm.	20
"	" "	160 ppm.	20
"	Checks		10
January	Hormodin powder	1000 ppm.	10
"	" "	3000 ppm.	10
"	" "	8000 ppm.	10
"	Hormodin A	20 ppm.	10
"	" "	40 ppm.	10
"	" "	80 ppm.	10
"	" "	160 ppm.	10
"	" "	200 ppm.	10
"	Checks		10

Port Orford White-cedar, cont.:

Time of P Planting	Treatment			Number of Cuttings
March	Hormodin	powder	1000 ppm.	10
"	"	"	3000 ppm.	10
"	"	"	8000 ppm.	10
"	Checks			10
			total	230

Western white pine:

November	Hormodin	powder	3000 ppm.	20
"	"	"	8000 ppm.	20
"	Hormodin	A	40 ppm.	20
"	"	"	80 ppm.	20
"	"	"	160 ppm.	20
"	"	"	200 ppm.	20
"	Checks			10
January	Hormodin	powder	3000 ppm.	10
"	"	"	8000 ppm.	10
"	Hormodin	A	40 ppm.	10
"	"	"	80 ppm.	10
"	"	"	160 ppm.	10
"	"	"	200 ppm.	10
"	Checks			4
March	Hormodin	powder	1000 ppm.	10
"	"	"	3000 ppm.	10
"	"	"	8000 ppm.	10
"	Checks			10
			total	234

Western weeping hemlock:

November	Hormodin	powder	1000 ppm.	10
"	"	"	3000 ppm.	10
"	"	"	8000 ppm.	10
"	Checks			10
January	Hormodin	powder	1000 ppm.	10
"	"	"	3000 ppm.	10
"	"	"	8000 ppm.	10

Western weeping hemlock, cont.:

Time of Planting	Treatment		Number of Cuttings
January	Hormodin A	20 ppm.	10
"	" "	40 ppm.	10
"	" "	80 ppm.	10
"	" "	160 ppm.	10
"	Checks		10
		total	110

Shipmast locust:

Time of Planting	Treatment		Number of Cuttings
January	Hormodin powder	1000 ppm.	20
"	" "	3000 ppm.	20
"	" "	8000 ppm.	20
"	Hormodin A	80 ppm.	20
"	" "	160 ppm.	20
"	Checks		10
		total	110

Red alder:

Time of Planting	Treatment		Number of Cuttings
January	Hormodin powder	1000 ppm.	20
"	" "	3000 ppm.	20
"	" "	8000 ppm.	20
"	Hormodin A	20 ppm.	20
"	" "	40 ppm.	20
"	" "	80 ppm.	20
"	" "	160 ppm.	20
"	Checks		10
		total	150

II. EXPERIMENTS WITH SEEDLINGS

Seedling Stock

Seedling stock was obtained from the Oregon Forest Nursery 8 miles north of Corvallis. Since this nursery does not grow western white pine a request for 100 western white pine seedlings was filled by the Wind River Nursery of the U. S. Forest Service at Carson, Washington. Sugar pine is especially difficult to field plant or transplant because of tender roots. A request was sent to the Durbin Nursery of the U. S. Forest Service at Susanville, California, for sugar pine planting stock, but this nursery is not growing sugar pine stock at the present time.

For transplanting 1:0 stock was used. For field planting 2:0 stock was used.

Nursery space:

Transplanting was done on the space reserved for school experiments on the Oregon Forest Nursery.

Field space:

Field planting was carried out on a selected area on the McDonald Forest. This area is located in SE 1/4 NE 1/4, Section 2, T 11 S, R 5 W just below the ridge road at the point of departure of the spur road to Peavy's cabin. This area was prepared by removing the most dense vegetation, largely bigleaf maple. This area is a good timber growing site of gentle slope and adequate protection from unfavorable elements.

Time of planting seedlings:

Planting of seedlings both in the transplant beds and in the field was done during the period of March 11 to 15.

Treatment of seedlings:

1. Powder treatment:

In the powder treatment of seedlings the powder was put into a paper bag; the roots of a bunch of seedlings were then inserted into the bag and the bag shaken vigorously enough to insure good distribution of the powder over the roots. Before the roots were powdered, they were dipped into water; this dipping in water is necessary to allow the active ingredient to go into solution so that it can be absorbed by the plant. The seedlings after treatment were planted in the transplant beds and in the field.

The powder used in seedling treatments was indolebutyric acid in talc in concentrations of 250, 500, and 1000 parts per million. The concentration of 1000 ppm. was obtained from the Merck Chemical Company. The 250 ppm. was prepared by mixing two ounces of the 1000 ppm. powder with 6 ounces of powdered talc. The 500 ppm. was prepared by mixing three ounces of the 1000 ppm. with three ounces of powdered talc. This mixing was done by putting these ingredients into a ball mill loaned the writer by Dr. Christensen of the Organic Chemistry Department, Oregon State College. The powders were mixed for one hour and 30 minutes.

2. Liquid hormone treatment:

In the liquid treatments the roots of the seedlings were placed in solutions of Hormodin A for 24 hours. The concentrations used were 5, 10, and 20 ppm. The depth of the solutions was sufficient to cover the roots. The solutions were maintained at room temperature or about 70 degrees F. during treatment. After treatment the seedlings were planted at once.

3. Vita Flor treatment:

The seedling roots were soaked for 14 hours at room temperature in a solution of Vita Flor, using a concentration of two drops to one quart.

Seedlings planted--species, treatment, number of seedlings

Transplant seedlings:

Species	Treatment	Number of Seedlings
Douglas-fir	Hormodin powder 250 ppm.	20
" "	" " 500 ppm.	20
" "	" " 1000 ppm.	20
" "	Hormodin A 5 ppm.	20
" "	" " 10 ppm.	20
" "	" " 20 ppm.	20
" "	Vita Flor 2 drops per qt.	20
" "	Checks	10
	total	150

Species	Treatment	Number of Seedlings
Port Orford White-Cedar	Hormodin powder 250 ppm.	10
" " "	" " 500 ppm.	10
" " "	" " 1000 ppm.	10
" " "	Hormodin A 5 ppm.	10
" " "	" " 10 ppm.	10
" " "	" " 20 ppm.	10
" " "	Vita Flor 2 drops per qt.	10
" " "	Checks	10
	total	80

Species	Treatment	Number of Seedlings
Western Yellow Pine	Hormodin powder 250 ppm.	10
" " "	" " 500 ppm.	10
" " "	" " 1000 ppm.	10
" " "	Hormodin A 5 ppm.	10
" " "	" " 10 ppm.	10
" " "	" " 20 ppm.	10
" " "	Vita Flor 2 drops per qt.	10
" " "	Checks	10
	total	80

Field planting seedlings:

Species	Treatment	Number of Seedlings
Douglas-fir	Hormodin powder 250 ppm.	10
" "	" " 500 ppm.	10
" "	" " 1000 ppm.	10
" "	Hormodin A 5 ppm.	10
" "	" " 10 ppm.	10
" "	" " 20 ppm.	10
" "	Vita Flor 2 drops per qt.	10
" "	Checks	10
	total	80

Field planting seedlings, cont.:

Species	Treatment	Number of Seedlings
Port Orford White-cedar	Hormodin powder 250 ppm.	10
" " "	" " 500 "	10
" " "	" " 1000 "	10
" " "	Hormodin A 5 "	10
" " "	" " 10 "	10
" " "	" " 20 "	10
" " "	Vita Flor 2 drops per qt.	10
" " "	Checks	10
		80
Western Yellow Pine	Hormodin powder 250 ppm.	10
" " "	" " 500 "	10
" " "	" " 1000 "	10
" " "	Hormodin A 5 "	10
" " "	" " 10 "	10
" " "	" " 20 "	10
" " "	Vita Flor 2 drops per qt.	10
" " "	Checks	10
		80
Western white pine	Hormodin powder 250 ppm.	10
" " "	" " 500 "	10
" " "	" " 1000 "	10
" " "	Hormodin A 5 "	10
" " "	" " 10 "	10
" " "	" " 20 "	10
" " "	Vita Flor 2 drops per qt.	10
" " "	Checks	10
		80

III. EXPERIMENTS WITH SEEDS

Seed Sources:

Douglas-fir and Port Orford cedar seed were obtained from the Oregon Forest Nursery. Western white pine seed was obtained from the Savenac Nursery. Sugar pine seed was obtained from the Forest Service Nursery at Susanville, California.

Nursery space:

Space reserved for the School of Forestry at the Oregon Forest Nursery was used.

Treatments:

1. Powder treatments:

   The same materials and concentrations of powder were used on the seeds as were used on the seedlings. The method of application was by wetting the seed with water and then stirring the powder into the seed, using a quantity sufficient to give the seed a light uniform coat of powder. The seeds were then planted in rows, 100 seeds to a 40 inch row, and covered with 1/4 inch of sand; burlap was placed over the top of these seedings.

2. Liquid treatments:

   Hormodin A in the same concentrations as used on the seedlings was used. The method of application was to soak the seeds 14 hours in the solutions followed by planting in the usual manner.

3. Vita Flor treatment:

Seed was soaked 14 hours in concentrations of two drops per quart and two drops per gallon. After soaking the seeds were planted in the usual manner.

Time of seeding:

Seed was sown on March 15 during a period of dry weather. The seedings were watered immediately after planting.

Seed units:

The seed samples were planted in rows putting 100 seeds in a 40 inch row. The rows were placed 6 inches apart and the blocks of different treatments were 8 inches apart. Each block contained a single treatment applied to the four rows, each row containing a different species.

The western white pine and sugar pine seeds were stratified in sand from December to the time of planting. The Port Orford White-cedar and Douglas-fir seeds were not stratified.

The seed bed was enclosed with one-quarter inch mesh hardware cloth to a height of 16 inches to avoid mouse damage. The top of this enclosure was covered with half lath shade, and three-quarter inch poultry netting was placed on top of the shade to keep out birds.

The burlap was removed from the white pine and sugar pine on March 29, at which time these seedlings were emerging.

Seeds planted

Species	Treatment	Number of seeds
Douglas-fir	Hormodin powder 250 ppm.	100
" "	" " 500 ppm.	100
" "	" " 1000 ppm.	100
" "	Hormodin A 5 ppm.	100
" "	" " 10 ppm.	100
" "	" " 20 ppm.	100
" "	Vita Flor 2 drops per qt.	100
" "	" " 2 drops per gal.	100
" "	Checks	100
	total	900
Port Orford White-Cedar	Hormodin powder 250 ppm.	100
" " "	" " 500 ppm.	100
" " "	" " 1000 ppm.	100
" " "	Hormodin A 5 ppm.	100
" " "	" " 10 ppm.	100
" " "	" " 20 ppm.	100
" " "	Vita Flor 2 drops per qt.	100
" " "	" " 2 drops per gal.	100
" " "	Checks	100
	total	900
Western White Pine	Hormodin powder 250 ppm.	100
" " "	" " 500 ppm.	100
" " "	" " 1000 ppm.	100
" " "	Hormodin A 5 ppm.	100
" " "	" " 10 ppm.	100
" " "	" " 20 ppm.	100
" " "	Vita Flor 2 drops per qt.	100
" " "	" " 2 drops per gal.	100
" " "	Checks	100
	total	900

Seeds planted, cont.

Species	Treatment	Number of seeds
Sugar pine	Hormodin powder 250 ppm.	100
" "	" " 500 ppm.	100
" "	" " 1000 ppm.	100
" "	Hormodin A 5 ppm.	100
" "	" " 10 ppm.	100
" "	" " 20 ppm.	100
" "	Vita Flor 2 drops per qt.	100
" "	" " 2 drops per gal.	100
" "	Checks	100
		total 900

RESULTS AND CONCLUSIONS

The objective of this research was to establish a program of research in the use of the synthetic plant hormones in the propagation of forest trees. Since this research will cover a long period of time the results available before the end of the current growing season can not be complete. The results are therefore necessarily rather preliminary; they indicate the direction of the work to follow for this program.

Since the work with cuttings was carried out in the greenhouse, this part of the program has been advanced farther than the work with seeds and seedlings.

Results with Cuttings

Douglas-fir (*Pseudotsuga taxifolia*)--See Table I.

The results with Douglas-fir are not yet advanced to the point where definite conclusions can be made safely. The November cuttings appear very thrifty, and the cuttings give every indication of rooting within a limited period of time, probably within two months. The basal ends of the cuttings either have a very definite callus right up to the end of the base or the basal end has died back for a distance up to one inch with callus formed above that point; this does not appear to be due to the differences in treatment. Four control cuttings have died while the balance show light callusing. No leader growth was evident on these cuttings by April 12. The January cuttings have been more active than the November cuttings. A single specimen of the powder treated 8000 ppm. cuttings has produced three roots up to two inches long. Most of the rest of the cuttings are well callused and apparently are about to root. Leader growth is in progress on about half of the cuttings (April 12). There is no correlation between leader growth and concentration of treatment. The March cuttings are callusing satisfactorily, and leader growth is more active than in either the November or January cuttings.

Western white pine (<u>Pinus monticola</u>)--See Table II.

Table II shows that most of the November cuttings died; none have rooted, but a number have callused and will probably root in the course of time. The November cuttings were taken from wild stock in the vicinity of Valsetz, Oregon. This was poor stock but was the only material available at the time. The January cuttings were rooting to some extent (April 12) though the roots have not developed to the point where definite conclusions can be drawn. No significant difference is apparent between different treatments. Since these cuttings were obtained from seedling 2:0 nursery stock, they can hardly be considered as good material for cuttings. Following experiments will attempt to use better material for cuttings.

Port Orford White-cedar (Chamaecyparis lawsoniana)--See Table III.

Preliminary examinations indicated that the cuttings planted in November which received the stronger treatments, powder 8000 ppm. and Hormodin A 80 and 160 ppm., were sending out roots 45 days after planting. All concentrations had produced roots in 60 days while the higher concentrations had produced such a mass of roots that the cuttings could not be examined without injury to the roots. Six of the 10 controls had a few roots while the other controls had healthy calluses. These November cuttings were planted in the field on March 11. The cuttings planted in January showed satisfactory rooting after 45 days for all concentrations. Table III indicates that results are increasingly favorable as the concentrations increase so that the powder treatment at 8000 ppm. and Hormodin A at 160 ppm. give the best results within the range of concentrations used. Roots were just beginning to grow by April 12 on cuttings planted in March and given a powder treatment of 8000 ppm. All other treatments and the controls were callusing.

It may safely be concluded that under greenhouse conditions Port Orford White-cedar will root 90 to 100 per cent with a powder treatment of 8000 ppm. or a Hormodin A treatment of 160 ppm. No effect was noticeable on leader growth. The cuttings are considered satisfactorily rooted if they have three or more roots each one and one-half inches long or longer. Plate I shows a typical rooted cutting following a powder treatment at 8000 ppm. Hormodin A treatment of 160 ppm. gives the optimum results for the liquid treatment. This is comparable to the 8000 ppm. powder treatment. Plate III shows the best rooted cutting of the controls, and a callused though unrooted control. Plate II shows a typical cutting rooted with 1000 ppm. powder treatment, while Plate IV shows a typical cutting rooted with 3000 ppm.

Shipmast locust (Robinia pseudoacacia erectissima)-- See Table IV.

The results with shipmast locust seem confusing after Stoutemyer's report (63) that cuttings not given a special callusing treatment seldom rooted. Table IV indicates that this is not always the case. Fifty per cent rooting was obtained from 1000 ppm. and 8000 ppm. powder treatment only. One cutting of powder treatment 3000 ppm. rooted; Plate V and VII show cuttings rooted by these treatments. The cuttings receiving the callusing treatment before the hormone treatments show somewhat more consistent rooting than uncallused cuttings but in no case did they attain a 50 per cent rooting as with the two treatments of uncallused cuttings. The roots developed on locust cuttings were inclined to be long and thin; nodules were produced on all locust roots. Plate VI shows a cutting rooting after callusing and treatment with Hormodin A at 160 ppm. Results do not show significance between treatments and more work needs to be done before definite conclusions can be evaluated.

Red Alder (Alnus rubra)--See Table V.

Results with red alder were the least encouraging of all the species propagated. By April 12 varying degrees of mortality had occurred in all treatments except the controls. However, the only two specimens initiating roots were among the treated cuttings though callus was generally lacking in all the cuttings. The controls were all alive though no sign of rooting or callusing was evident. The net results are therefore almost wholly negative and new methods of technique and treatment should be investigated if further work is to be carried on with this species.

Western weeping hemlock (Tsuga heterophylla var...)--See Table VI.

A single specimen of this species rooted by April 12 while most of the November and the January cuttings had healthy calluses indicating that rooting would occur in the future. These results indicate that this rare variety of western hemlock will be successfully propagated for the first time.

Results with Seedlings

Transplants.

The transplants were planted on March 14 and 15. No results can be derived until after the current growing season. These transplants have only just commenced growth for the season (April 12.). The necessary arrangements have been made to care for these experiments during the summer and the ensuing year. Several students have worked with the writer in establishing these experiments; they will carry the work on during the coming year.

Field-planted seedlings.

Hormone treated field planting stock was planted on March 12. Definite results will not be available until after the current growing season. Future work will be conducted by the same students who are familiar with the cuttings and seedings.

Results with Seeds

The hormone treated seed experiments were established on March 15. The white pine and sugar pine seed which was stratified over the winter commenced germination by April 5. Seed of Port Orford White-cedar and Douglas-fir was not yet sprouting by April 12. As yet there is no apparent difference between samples of the two species of pine due to different treatments within each species. Future work will be conducted by the students who helped on this program during the past year. Definite results should be available after the current growing season.

Discussion

Cuttings.

For the most part the propagation of forest trees from cuttings by the present known methods does not hold great promise as a means of reproducing forest trees at the present time. Results though significant for the best rooting species are not promising for cheap large scale production.

Work with Douglas-fir seems to indicate that although this species can root very successfully in the greenhouse it is so slow as to raise a question in the writer's mind as to the feasibility of so propagating Douglas-fir. New developments adapted to outdoor application are necessary if this species is to be so propagated.

The work with western white pine has been hampered in the present program by a lack of cutting materials. The results prove that western white pine is capable of being propagated from cuttings. Results up to the present time do not allow definite conclusions as to the future of such propagation. More work is needed.

Port Orford White-cedar gives uniformly good rooting under greenhouse conditions for all concentrations. The planting of cuttings of this species under outdoor conditions to test the possibilities of so propagating this species seems the next logical step. The fact that Jacobs (38) reports the successful large scale rooting of cuttings in Australia may be an indicator of possibilities for this region.

According to Stoutemyer (63) the rooting of black locust cuttings is progressing satisfactorily for the production of forest planting stock. The writer's experience indicates that more work should be conducted with this species since his results did not conform with the report made by Stoutemyer that uncallused cuttings rarely strike root.

The red alder seems to promise the least positive results among the species worked with. It appears that if red alder is to be propagated from cuttings, new and more effective methods of treatment are necessary.

The expected rooting of western weeping hemlock is encouraging since this rare and as yet unnamed variety of western hemlock possibly may not be propagated in any other manner. The two trees on Alsea Mountain from which the writer obtained cuttings are the only two trees known of this variety. Professor T. J. Starker of the School of Forestry mapped the location of these trees after his attention was called to their existense by loggers operating on Alsea Mountain. The writer planted some seed secured from cones on one of the trees in November; although the seed was planted in a flower pot in the greenhouse it did not germinate. Professor Starker also sent cuttings of this tree to the Boyce Thompson Institute of Plant Research at Yonkers, New York, where attempted rooting of cuttings resulted in failure. Robert Campbell, a student of the School of Forestry, grafted twigs of weeping hemlock on regular hemlock; results from this procedure are as yet uncertain. Indications from the present work show that this variety will be successfully propagated from cuttings before the current growing season is over.

The use of the Vitamin B factors had no significant effect on the rooting of cuttings. The application of two drops per gallon applied weekly in watering made no appreciable change in rooting or root growth on cuttings.

Seedlings.

Other investigators have shown both positive and negative results from treating seedlings with plant hormones. The present experiment should show the practicability of so treating seedlings in this locality within the next few years. If results are positive, the practice of treating seedlings can be easily adapted in reforestation.

Seeds.

The small amount of information available on the treating of forest tree seeds with hormones does not hold out much promise for these treatments. The negative results may be due to excess dosage. Promising results have been obtained by some investigators working on seeds of plants other than forest trees.

TABLE I

Douglas-fir cuttings

Planted: November 9, 1940

Date of results: April 12, 1941

Number	Treatments in ppm.		Roots under $1\frac{1}{2}$"	Total# rooted	Remarks	
20	Powder	1000	0	0	Callused	
20	"	3000	0	0	"	
20	"	8000	0	0	"	
20	Liquid	20	0	0	"	
20	"	40	0	0	"	; 2 dead
20	"	80	0	0	"	; 1 "
10	Controls		0	0	"	; 4 "
Planted: January 15, 1941						
Date of results: April 12, 1941						
10	Powder	1000	0	0	Callused	; 3 "
10	"	3000	0	0	"	
10	"	8000	1	1	"	; 1 "
10	Liquid	40	0	0	"	
10	"	80	0	0	"	
10	"	160	0	0	"	
10	Controls		0	0	Callusing	

Planted: March 9, 1941

Date of results: April 12, 1941

10	Powder 1000	0	0	Callusing
10	" 3000	0	0	"
10	" 8000	0	0	"
10	Controls	0	0	"

TABLE II

Western white pine cuttings

Planted: November 9, 1940

Date of results: April 12, 1941

Number	Treatment in ppm.	Roots under 1½"	Total# rooted	Remarks
20	Powder 3000	0	0	13 callusing; 7 dead
20	" 8000	0	0	7 " ; 13 "
20	Liquid 80	0	0	9 " ; 11 "
20	" 160	0	0	6 " ; 14 "
20	" 200	0	0	5 " ; 15 "
10	Controls	0	0	2 " ; 8 "

Planted: January 15, 1941

Date of results: April 12, 1941

Number	Treatment in ppm.	Roots under 1½"	Total# rooted	Remarks
10	Powder 8000	3	3	5 callused; 2 dead
10	Liquid 40	3	3	5 " ; 2 "
10	" 80	5	5	5 dead
10	" 160	0	3	2 callused; 5 "
10	" 200	0	5	5 "
4	Controls	0	0	3 " ; 1 "

Planted: March 10, 1941

Date of results: April 12, 1941

Number	Treatment in ppm.	Roots under 1½"	Total# rooted	Remarks
10	Powder 1000	0	0	8 callused; 2 dead
10	" 3000	0	0	5 " ; 2 "
10	" 8000	3	3	4 " ; 3 "
10	Controls	0	0	10 callusing

TABLE III

Port Orford White-cedar

Planted: November 9, 1940

Date of results: March 11, 1941

Number	Treatment in ppm.		Roots under $1\frac{1}{2}$"	Total# rooted	Remarks
20	Powder	1000	0	19	1 dead
20	"	3000	1	20	
20	"	8000	0	19	1 dead
20	Liquid	20	5	20	
20	"	40	4	20	
20	"	80	1	20	
20	"	160	0	20	
10	Controls		6	6	4 not rooted

Planted: January 15, 1941

Date of results: April 12, 1941

Number	Treatment in ppm.		Roots under $1\frac{1}{2}$"	Total# rooted	Remarks
10	Powder	1000	4	9	1 not rooted
10	"	3000	2	9	1 not rooted
10	"	8000	0	10	
10	Liquid	20	4	10	
10	"	40	3	10	
10	"	80	1	10	
10	"	160	0	10	
10	"	200	0	10	
10	Controls		5	5	5 not rooted

Planted March 12, 1941

Date of results April 12, 1941

10	Powder 1000	0	0	Callusing
10	" 3000	0	0	"
10	" 8000	3	3	" and rooting
10	Controls	0	0	"

TABLE IV

Shipmast locust

Planted: January 15, 1941

Date of results: April 12, 1941

Number	Treatment in ppm.		Roots under 1$\frac{1}{2}$"	Total# rooted	Remarks
10	Powder	1000	2	5	5 dead
10	"	3000	0	1	
10	"	6000	2	5	
10	Liquid	80	0	0	5 "
10	"	160	0	0	2 "
10	Controls		0	0	1 callused; 2 dead
Special callusing treatment before hormone treatment					
10	Powder	1000	3	4	5 dead
10	"	3000	2	0	5 "
10	"	6000	3	0	4 "
10	Liquid	80	3	0	6 "
10	"	160	3	2	7 "

TABLE V

Red alder

Planted: January 16, 1941

Date of results: April 12, 1941

Number	Treatment in ppm.		Roots under 1½"	Total# rooted	Remarks
10	Powder	1000	0	0	No callus; 3 dead
10	"	3000	1	1	" " ; 5 "
10	"	8000	0	0	" " ; 7 "
10	Liquid	20	0	0	" " ; 5 "
10	"	40	0	0	10 dead
10	"	80	0	0	10 "
10	"	160	0	0	No callus; 9 "
10	Controls		0	0	" "
Special callusing treatment before hormone treatment					
10	Powder	1000	0	0	No callus; 8 dead
10	"	3000	0	0	10 dead
10	"	8000	0	0	10 "
10	Liquid	20	0	0	10 "
10	"	40	0	0	No callus; 9 "
10	"	80	0	0	1 callused; 9 "
10	"	160	1	1	9 dead

TABLE VI

Western weeping hemlock

Planted: November 30, 1940

Date of results: April 12, 1941

Number	Treatment in ppm.	Roots under 1½"	Total# rooted	Remarks
10	Powder 1000	0	0	No callusing; 2 dead
10	" 3000	0	0	" " ; 2 "
10	" 8000	1	1	Some " ; 1 "
10	Controls	0	0	No " ; 3 "

Planted: January 15, 1941

Date of results: April 12, 1941

Number	Treatment in ppm.	Roots under 1½"	Total# rooted	Remarks
10	Powder 1000	0	0	Callusing
10	" 3000	0	0	"
10	" 8000	0	0	"
10	Liquid 20	0	0	"
10	" 40	0	0	"
10	" 80	0	0	"
10	" 160	0	0	"
10	Controls	0	0	Slight callusing

PLATE I

Port Orford White-cedar

Treatment--Powder 8000 ppm.

PLATE II

Port Orford White-cedar

Treatment--Powder 1000 ppm.

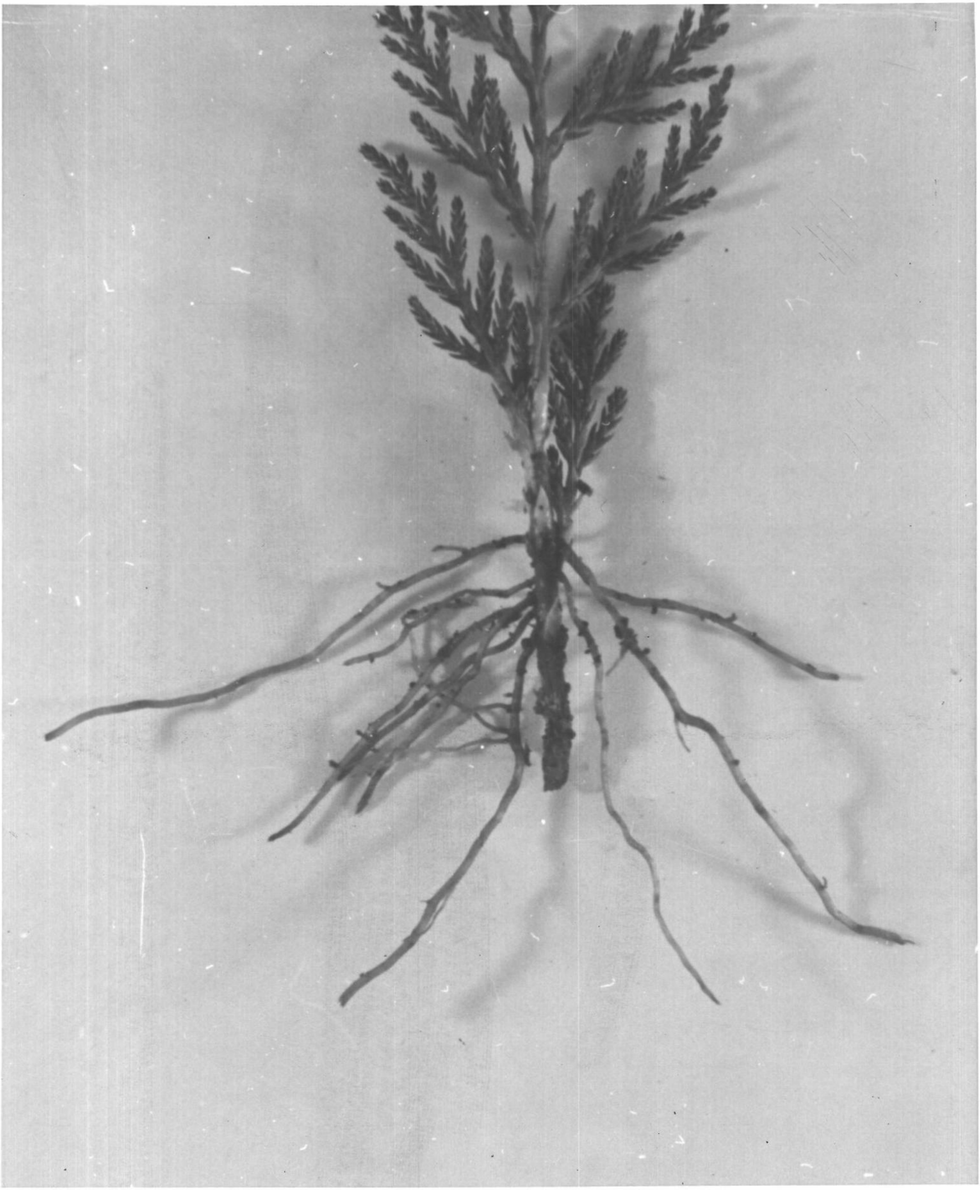


PLATE III

Port Orford White-cedar

Treatment--Control

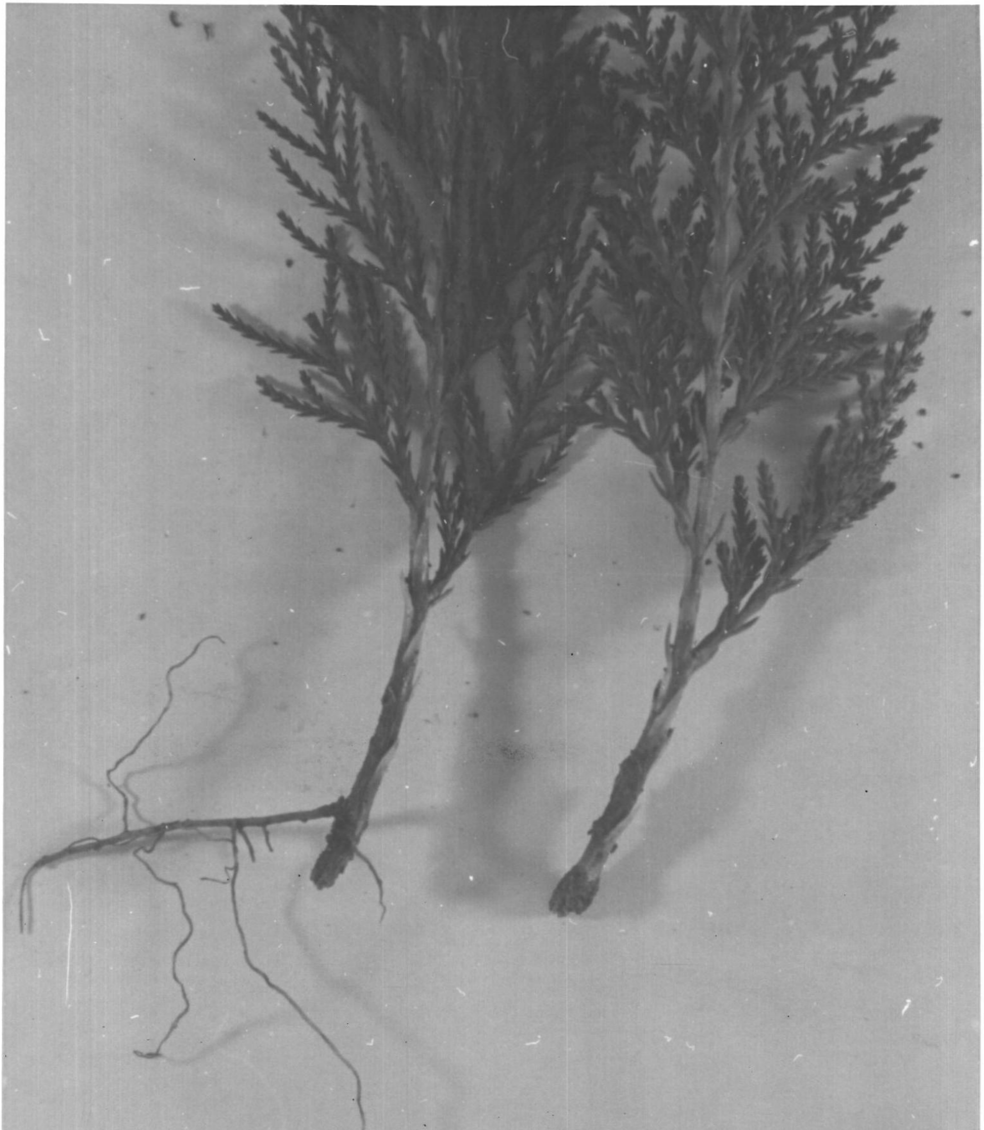


PLATE IV

Port Orford White-cedar

Treatment--Powder 3000 ppm.

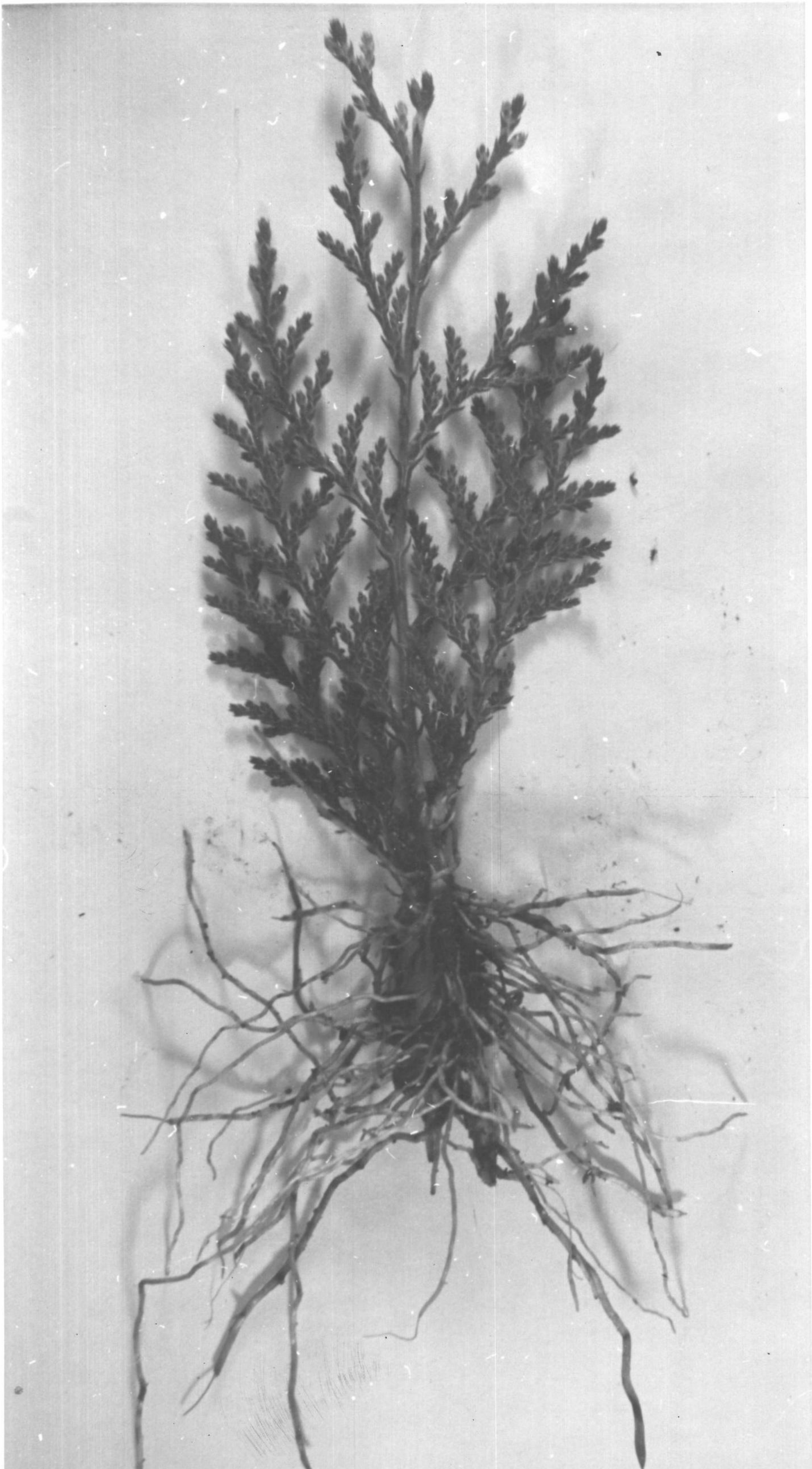


PLATE V

Black locust

Treatment--Powder 8000 ppm.;

no callusing treatment

PLATE VI

Black locust

Treatment--Hormodin A 160 ppm. for 24 hours; callused before receiving hormone treatment.

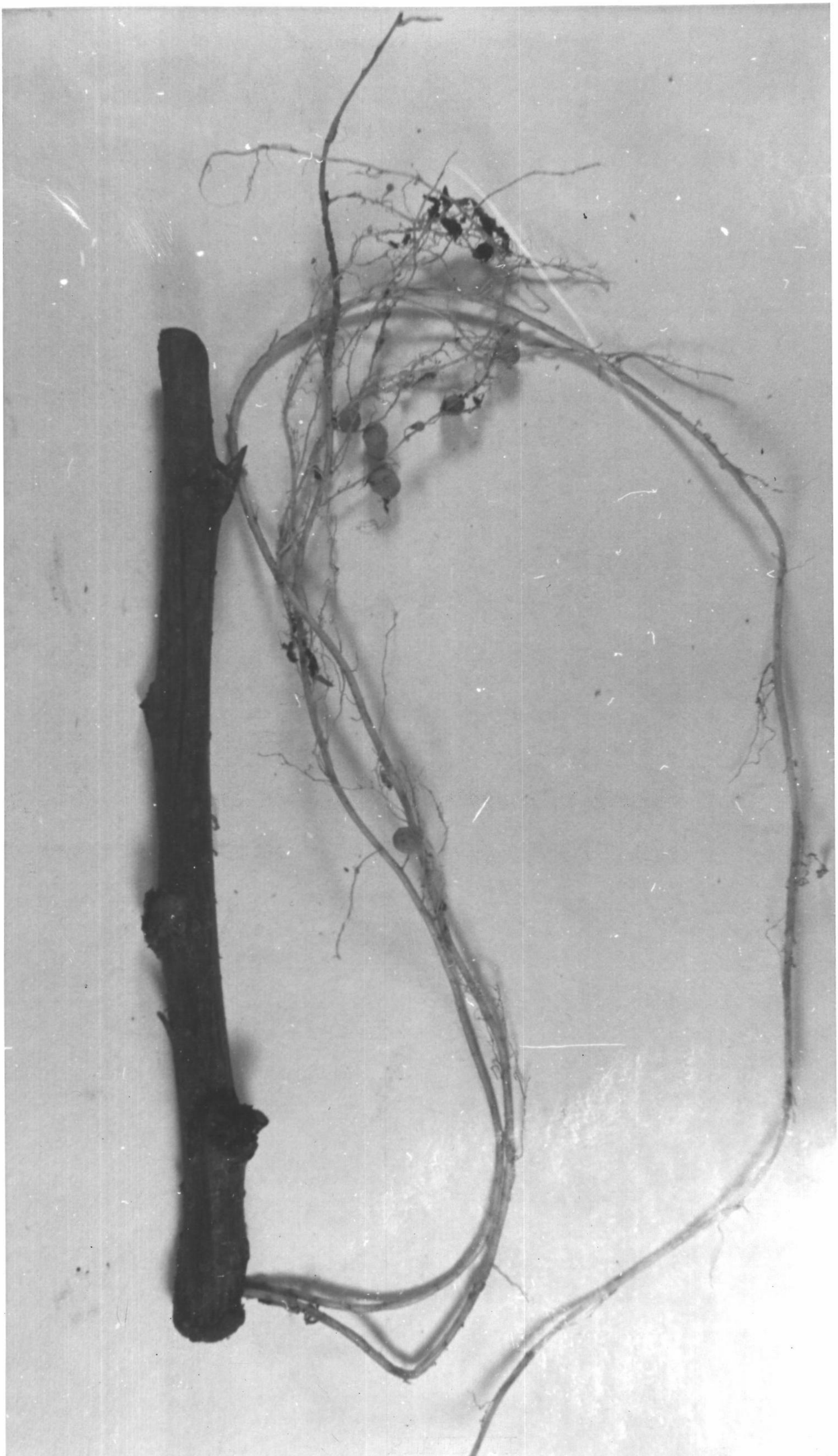
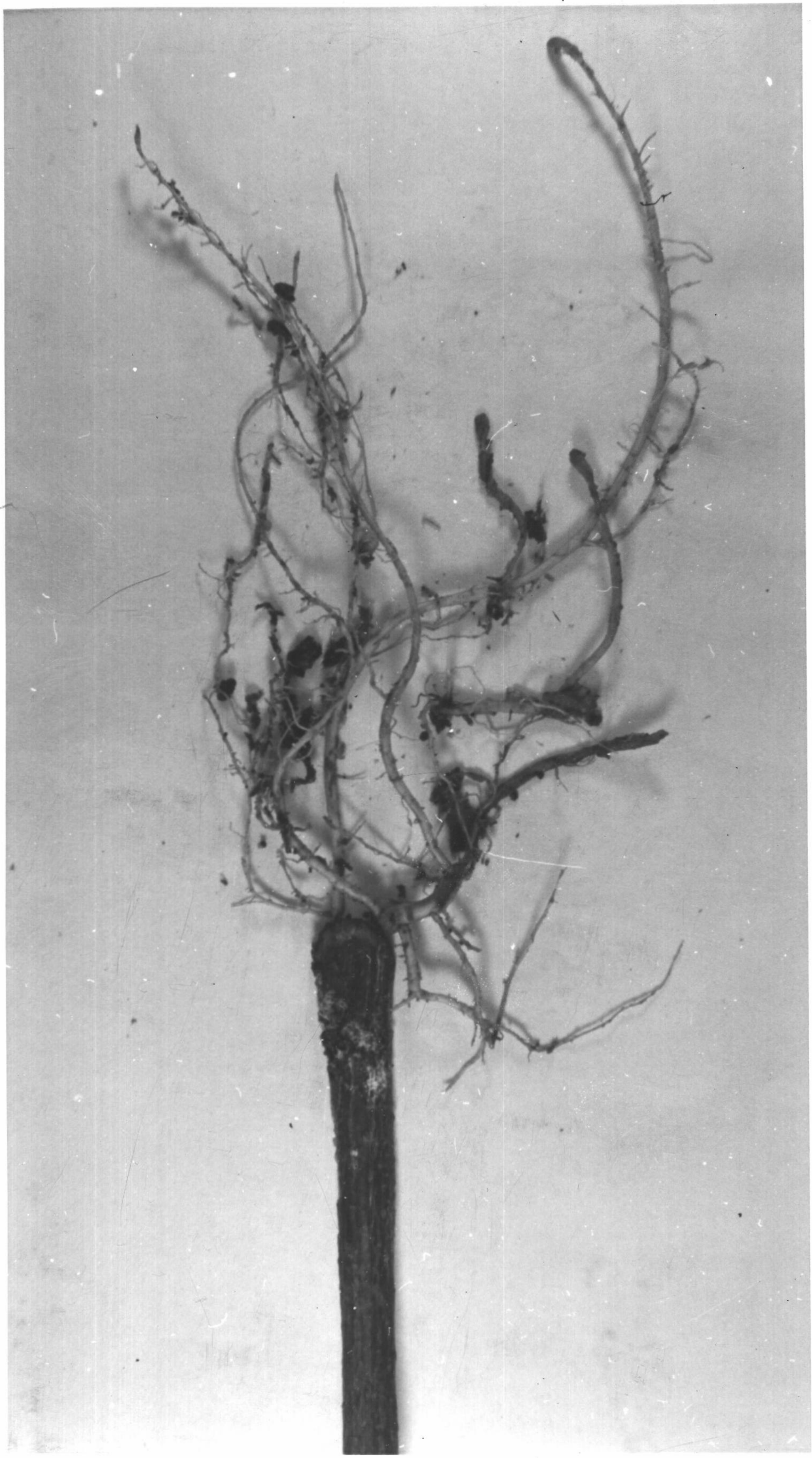


PLATE VIII

Black locust

Treatment--Powder 1000 ppm.;

no callusing treatment



GENERAL CONSIDERATIONS

The writer recognizes two factors which may have an important bearing on the possibilities for positive results in this field of hormone treatments in forest tree propagation.

The first factor is the quality and amount of humus in the soil. Most of the reports of positive results obtained from the use of hormones and vitamins come from the more southern states where the humus content of the soil is much less than the humus content of the more temperate zones. Greenhouse facilities using sterile sand also approach a condition low or lacking in organic content. The theory has been proposed and some proof given that the humus complex is a natural source of plant hormones and vitamins; hence, in the soils of low humus content the application of hormones and vitamins leads to favorable results.

The second factor is that of temperature. Experimental work shows that the lower the temperature the less activity results from the hormones. Before a freezing temperature is reached, the hormones are inactivated and they do not regain their powers on a subsequent rise in temperature. This difficulty is not encountered in the southern regions. Greenhouses are also maintained at optimum temperatures. Since the weather approached freezing temperatures after the present experiments were

were established, the possibility exists that the hormones may have been cooled below their critical temperature. If planting of seed or seedlings were delayed until continued warm weather was assured, it would be too late for best survival in planting.

The present experiments should help provide the answer to these questions in the use of plant hormones in propagating forest trees.

The report of Thiman and Delisle (71) that high concentrations of hormones applied to cuttings will inhibit the growth of buds did not seem to be borne out in the present experiments even though Hormodin A was applied in concentrations up to 200 ppm. for 24 hour treatments. Powder treatments were applied in concentrations up to 8000 ppm. No correlation was obtained in the experiments between top growth or precociousness in bud development and strength of treatment. Douglas-fir cuttings taken in November were without exception as much as a month later in initiating bud development than were cuttings taken in January and March. Treatments were of the same range of concentrations for cuttings taken at the different periods.

SUMMARY

Recent literature on the use of plant hormones in the propagation of forest trees was reviewed and discussed.

Six species of forest tree cuttings were treated

with plant hormones in an effort to induce rooting; these species include Douglas-fir, Port Orford White-cedar, western white pine, shipmast locust, western weeping hemlock, and red alder.

Four species of forest tree seedlings were treated with plant hormones and planted in the field; these seedlings include Douglas-fir, Port Orford White-cedar, western white pine, and ponderosa pine. Three species of forest tree seedlings, Douglas-fir, Port Orford White-cedar, and ponderosa pine, were treated with hormones and Vitamin B factors and transplanted in the Oregon Forest Nursery.

Four species of tree seeds, including Douglas-fir, Port Orford White-cedar, sugar pine, and ponderosa pine, were treated with plant hormones and Vitamin B factors and planted in the Oregon Forest Nursery.

The treatments and procedures used were those giving best results in previous work with plant hormones. The rooting medium for the cuttings consisted of one part Canadian peat moss to two parts Santiam River sand. The work with the cuttings was carried out under greenhouse conditions.

The results with the cuttings indicate that almost any species of forest tree may be propagated by cuttings through the appropriate use of plant hormones under properly controlled conditions of temperature and humidity.

Port Orford White-cedar gave the most rapid and consistent results while red alder gave the least positive results. Shipmast locust did not give the results expected from the reports given by other workers with shipmast locust. Results from the experiments with seeds and seedlings will not be available until after the current (1941) growing season.

BIBLIOGRAPHY

1. Adams, Walter and H. Britton Logan Jr. 1940. America reports on Vitamin B_1. Better Homes and Gardens 18(6):15, 78, 82.

2. Afanasiev, Michel. 1939. Effect of indolebutyric acid on rooting of greenwood cuttings of some deciduous forest trees. Journal of Forestry 37 (1):39-47.

3. Anonymous. 1940. Bulletin 106-107. Galen Manufacturing Co., Berkeley, California. (unpublished)

4. Anonymous. 1940. Plant Hormone experiments. II. Vitamin B_1 experiments. Turtox News 18(12):1. General Biological Supply House Inc. Chicago, Illinois.

5. Bonner, David M. and James Bonner. 1940. On influence of various growth factors on the growth of green plants. American Journal of Botany 27(1):38-43.

6. ______ ________ and Jesse Green. 1938. Vitamin B_1 and the growth of green plants. Botanical Gazette 100:226-237.

7. Chadwick, L. C. 1940. Further experiments on the rooting of evergreen cuttings. Nursery Notes 10(1):5-12. Department of Horticulture, Ohio State University.

8. _________ _____ 1940. Effect of Synthetic Growth Substances on Seed. Nursery Notes 10(1): Department of Horticulture, Ohio State University.

9. Cooper, W. C. and F. W. Went. 1938. Effect on root formation of retreating cuttings with growth substances. Science n.s. 87(2261):390.

10. Croxall, H. E. and L. Ogilvie. 1940. The incorporation of growth hormones in seed dressings. Journal of Pomology and Horticultural Science 17(4):362-384.

11. Davis, L. L. 1940. Hastening crab-apple seed (Pyrus baccata) germination by fungicidal treatment. Nursery Notes by L. C. Chadwick. 9(3):16. Department of Horticulture, Ohio State University.

12. Detwiler, S. B. 1937. The History of shipmast locust. Journal of Forestry 35(8):709-712.

13. Deuber, Carl G. and John L. Farrar. 1940. Vegetative propagation of Norway spruce. Journal of Forestry 38(7):578-585.

14. Doran, William L., Robert P. Holdsworth, and Arnold D. Rhodes. 1940. Propagation of white pine by cuttings. Journal of Forestry 38(10):817.

15. Durus, W. P. 1939. Propagation and improvement of horticultural plants. Oregon State College Extension Bulletin 529.

16. ____________ 1939. Grafting and budding. Oregon State College Bulletin 528.

17. Flory, Walter S. 1937. Utilization of plant hormones by the commercial nursery. Florists Exchange and Horticultural Trade World 89(15):8.

18. Glasgow, Ray and Darwin Clark. 1938. The use of "Auxilin" in plant propagation. (Silviculture project at School of Forestry at Oregon State College.) (unpublished)

19. Grace, N. H. 1940. Vegetative propagation of conifers IV. Effects of cane sugar, ethyl mercuric phosphate, and indolylacetic acid in talc dust on the rooting of Norway spruce. Canadian Journal of Research 18 Sec. C. (1):13-18.

20. ____________ 1937. Physiological curve of response to phytohormones by seeds, growing plants, cuttings, and lower plant forms. Canadian Journal of Research 15 Sec. C. (11):538-546.

21. ____________ 1938. Phytohormones and seed disinfection. Nature 142(2):77.

22. ____________ 1940. Vegetative propagation of conifers V. The effect of indolylacetic acid and nutrient solutions on the rooting of Norway spruce cuttings. Canadian Journal of Research 18 Sec. C. (4):122-128.

23. ____________ 1939. Effects of cane sugar, ethyl mercuric phosphate, and indolylacetic acid in talc on the rooting of cuttings. Canadian Journal of Research 17 Sec. C. (10):321-333.

24. ____________ 1939. Responses of dormant cuttings of Lonicera tatarica to solutions of cane sugar and indolylacetic acid. Canadian Journal of Research 17 Sec. C. (10):334-338.

25. ________ 1939. Vegetative propagation of conifers I. Rooting of cuttings taken from the upper and lower regions of a Norway spruce tree. Canadian Journal of Research 17 Sec. C (6): 178-180.

26. ________ 1939. Vegetative propagation of conifers III. Effect of month of collection on the rooting of dormant Norway spruce cuttings. Canadian Journal of Research 17 Sec. C. (11):376-379.

27. ________ 1939. Vegetative propagation of conifers II. Effects of nutrient solutions and phytohormone dusts on rooting of Norway spruce cuttings. Canadian Journal of Research 17 Sec. C. (9):312-316.

28. Griffith, B. G. 1939. Effect of indolebutyric acid and alpha naphalene-acetic acid on rooting of cuttings of some deciduous and evergreen trees of the Pacific Northwest. Thesis for degree of Doctor of Philosophy. University of Washington. (unpublished)

29. ______________ 1940. Effect of indolebutyric acid, indoleacetic acid, and alpha naphthalene-acetic acid on rooting of cuttings of Douglas-fir and Sitka spruce. Journal of Forestry 38(6): 496-501.

30. Gross, Eugene W. 1940. The responses of shoots of mungo bean seedlings growing in solutions of 3-indole-acetic acid. American Journal of Botany 27(6):371-376.

31. Gruenhagen, R. H. September 1940. Growth substances of doubtful benefit for treatment of pine seeds. Journal of Forestry 38(9):739-740.

32. Hall, Ralph C. 1937. Growth and yield in shipmast locust on Long Island and its relative resistance to locust borer injury. Journal of Forestry 35(8): 721-727.

33. Hitchcock, A. E. 1928. Effect of peat moss and sand on the rooting response of cuttings. The Botanical Gazette 86:121-148.

34. ______________ and P. W. Zimmerman. 1939. Comparative activity of root-inducing substances and methods for treating cuttings. Boyce Thompson Institute for Plant Research Contributions 10: 461-480.

35. ______________________________1940. Effects obtained with mixtures of root-inducing and other substances. Boyce Thompson Institute of Plant Research Contributions 11(2):143-160.

36. ______________________________1938. Root-inducing substances. Florists Exchange and Horticultural Trade World 91(26):11.

37. ______________________________1940. Comparative root-inducing activity of individual substances and mixtures. Nursery Notes by L.C. Chadwick 9(3):13. Department of Horticulture, Ohio State University.

38. Jacobs, M. R. 1939. The vegetative reproduction of forest trees. 1. Experiments with cuttings of P. radiata Don. Bulletin No. 25 Commonwealth Forestry Bureau. Canberra, Australia.

39. Kirkpatrick, Henry Jr. 1939. The use of root-inducing substances. Florists Exchange and Horticultural Trade World 92(14):19.

40. Laurie, Alex and L. C. Chadwick. 1931. Vegetative propagation. The Modern Nursery. The Macmillan Company. New York.

41. Lindquist, Bertil. 1939. Om produktionem avtillvaxthormoner hos nigra i de vordsvenska rahumusmarkerna vauliga svampmycel. (Production of growth hormones by some fungus mycelia occurring in raw humus of northern Sweden.) Tidsskr. Skogbruk 47(12):381-390.

42. Logan, H. Britton Jr. 1939. News of an exciting discovery. Better Homes and Gardens 18(2):13.

43. McCulloch, W. F. 1939. Vegetative propagation of Douglas-fir. School of Forestry, Oregon State College (unpublished).

44. McCully, Kenneth. 1939. Some experience in the propagation of carnations. Florists Exchange and Horticultural Trade World 92(14):19.

45. Meahl, R. P. 1940. Effect of pretreating evergreen cuttings with alochol before using root-promoting substance in powder form. Nursery Notes by L. C. Chadwick 9(3):15. Department of Horticulture, Ohio State University.

46. Mirov, N. T. 1938. Vegetative propagation of white pine as a possible method for blister rust control. Journal of Forestry 36(8):807-808.

47. ________ 1940. Tested methods of grafting pine. Journal of Forestry 38(10):768-777.

48. Nicholson, Arnold. 1940. Deuces wild in the plant game. The Country Gentleman. 110(1):12-13, 58.

49. Pearce, H. L. 1938. Experiments with growth controlling substances.--II, response of fruit tree cuttings to treatment with synthetic root-forming substances. East Malling (Kent) Research Station Annual Report 26:157-166. East Malling, England.

50. ________ 1938. Experiments with growth controlling substances. Annals of Botany n. s. 2:227-236.

51. Plank, Donald K. 1939. Root response of slash pine seedlings to indolebutyric acid. Journal of Forestry (37(6):497-498.

52. Schaad, L. O. 1939. The use of root-promoting substances in the propagation of cuttings. A Thesis Submitted to Oregon State College. (unpublished)

53. Schreiner, E. J. 1939. The possibilities of the clone in forestry. Journal of Forestry 37(1): 61-62.

54. ________ 1937. Improvement of forest trees. Yearbook of Agriculture 1937. pp. 1242-1279.

55. Smith, C. L. and L. D. Romberg. 1939. A method for treatment of cuttings and roots of the pecan with root-inducing chemicals. Plant Physiology 14(1): 177-178.

56. Snow, A. G. 1938. Use of indolebutyric acid to stimulate the rooting of dormant aspen cuttings. Journal of Forestry 36(6):582-587.

57. ________ 1939. Chemically induced rooting of sugar maple cuttings. Northeastern Forest Experiment Station. U. S. Department of Agriculture Technical Note 27.

58. ________ November 30, 1940. Rooting White Pine Cuttings. Occasional Paper No. 11. U.S.D.A. North-

eastern Forest Experiment Station.

59. __________ March 1941. White Pine Propagation. Journal of Forestry 39(3):332-333.

60. Stephenson, R. B. 1940. Effect of various growth regulating substances on the growth of lettuce seedlings (variety grand rapids). Nursery Notes by L. C. Chadwick 9(3):13. Department of Horticulture, Ohio State University.

61. Stoutemyer, V. T., J. R. Jester, and F. L. O'Rourke. 1940. Propagation of black locust clones by treating hardwood cuttings with growth substances. Journal of Forestry 38(7):558-563.

62. Stoutemyer, V. T. 1940. Vitamin B_6 and root cuttings. American Nurseryman 71(6):11-13, 32.

63. ________________ 1938. Talc as a carrier of substances inducing root formation in softwood cuttings. American Society for Horticultural Science Proceedings 36:817-822.

64. Stuart, N. W. and P. C. Marth. 1937. Composition and rooting of American holly cuttings as affected by treatment with indolebutyric acid. American Society Horticultural Science Proceedings 34:839-844.

65. Swartley, John W. 1940. Effects of synthetic growth substances on the rooting of softwood cuttings of woody ornamentals. Nursery Notes by L. C. Chadwick 9(1):2. Department of Horticulture, Ohio State University.

66. ________________ 1940. Effects of synthetic growth substances on transplants. Nursery Notes by L. C. Chadwick 9(12):1-13. Department of Horticulture, Ohio State University.

67. Swingle, C. F. 1937. Experiments in propagating shipmast locust. Journal of Forestry 35(8):713-720.

68. ______________ 1940. Regeneration and vegetative propagation. Botanical Review 6(7):301-355.

69. Tang, Pei-Sung and Shih-Wei Loo. 1940. Tests on after-effects of auxin seed treatment. American Journal of Botany 27(6):385-386.

70. Thiman, K. V. 1938. Specific factors other than auxin affecting growth and root formation. Plant Physiology 13(1):55-80.

71. ____________ and Albert L. Delisle. 1939. The vegetative propagation of difficult plants. Journal of the Arnold Arboretum 20(1):116-136.

72. Tincker, M. A. H. S. Some root-forming substances in relation to one another, to plant metabolism, and to growth. Annals of Applied Botany 27(2):184-195.

73. Watkins, John V. 1937. Experiments with hormodin on tropical and semitropical plants. Florists Exchange and Horticultural Trade World 89(3):20, 36.

74. Welmer, D. E. 1938. Treatment of seeds with indolebutyric acid and its effects. Association of Official Seed Analysts of North America Proceedings 30: 263-268.

75. Went, F. W. 1938. Hormones and the analysis of growth. Plant Physiology 13(3):437-449.

76. __________, James Bonner, and G. C. Warner. 1938. Aneurin and the rooting of cuttings. Science n. s. 87(2251):170-171.

77. Yerkes, G. E. 1938. Treat cuttings with indolebutyric acid. American Nurseryman 67(9):10-11.

78. ____________ 1932. Propagation of trees and shrubs. U. S. Department of Agriculture Farmers Bulletin No. 1567.

79. Zach, L. W. 1940. Vegetative propagation of forest trees with the aid of hormones. A Thesis submitted to the School of Forestry at Oregon State College (unpublished).