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STIMULATION OF ROOT GROWTH ON CUTTINGS FROM HARDWOOD FOREST TREES

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Certain trees and shrubs may more easily be propagated from cuttings than from seed. Others may be regenerated by root or stem layering. It is well known that new trees of willow, poplar or sycamore may readily be produced by cuttings separated from the parent tree and planted in soil or sand under favorable conditions of temperature and moisture.

Some hardwood species on the other hand, are extremely difficult to reproduce either by seed, layering or cutting. Perhaps the most rebellious in this respect is the basswood. The seed of this species will resist ordinary methods used in germinating for several years and no attempts have yet been successful in propagating this tree from cuttings, or by layering.

In the hope of discovering a method of stimulating rooting of basswood cuttings as well as other trees difficult of regeneration by seed the work recounted in this report was undertaken. It was a major study taken by Mr. G. C. Hutchings, for a Master degree in the Forestry Department at the Iowa State College during the year 1926-27.

Scions were taken from the new shoots of green ash, soft maple, basswood and Carolina poplar and planted in sand in the greenhouse, after being treated with certain liquid chemical reagents which might stimulate the growth of roots. Poplars, which root readily from cuttings without stimulants of any kind, were included merely as a check in that injuries produced by the stimulants would in this manner be shown.

During the course of this experiment the tests were also made by setting some cuttings in potatoes, other in Sphagnum moss. For this purpose scions of white oak, slippery elm, black walnut and butternut were used.

Certain other tests were also made in order to find the relative value of a continuous application of the solution as compared with treatment for a very limited time. For such tests cuttings of white oak, soft maple, hard maple, slippery elm and the willow were employed.

By a rather wide reading of the literature available for this line of investigation a good many helpful suggestions were obtained especially from the reports of Curtiss (1), who has shown that very marked stimulation of root growth may result on cuttings of certain woody plants by the use of Potassium permanganate. Faivre (2), has proved that root growth in cuttings is dependent upon the food stored in the twigs. Knight (3) (4), has shown that a Manganese Dioxide, Manganese Sulphate, Aluminum Chloride, Ferrie Chloride or Ferrie Sulphate, or Boric Acid at times show stimulating effects in cutting upon fruit trees. He concluded that the amount of callus formation was not indicative of the amount of root growth; — these being two distinct processes; That callus formation is favored by high water content of soil; and that root production is favored by a lower water content and efficient aeration. He also discovered that nutrient solutions when applied as possible stimulants for root growth on cuttings, are on the whole injurious. Rothacker (5), states that immature twigs can be caused to absorb cane sugar and stored in such a form as to make it available as a food for root growth in cuttings. Small (6), while working with cuttings of certain shrubs among which were Privet and Veronica, obtained a marked increase in the root growth when treated with Acetic acid solution of dilute concentration. He stated that the green shoot uses up the acid Carbon Dioxide in order to produce sugars and starch during the day while, the roots, in respiring below ground, are always producing, but never using up the same acidic gas. Zimmerman (7), in his experiments on aeration, found that cuttings placed at varying depths up to two feet in the soil produced roots in conformity with the species rather than according to the depths to which they were set.

Materials and Methods

A total of 1750 cuttings of the species named were taken on November 24 and 25, 1926, from sprouts produced during the previous seasons. Each cutting was made with sharp prunning shears, the basal cut being made directly below a bud. As far as possible each cutting was made approximately 11 inches in length. They were tied in bundles of fifty and buried immediately in the storage pit, which was two feet deep in a sandy soil and on a well drained slope. On February second all cuttings were taken from the pit and planted in the greenhouse. At the time the material was in a satisfactory condition, the buds intact and unswollen and callus formations entirely lacking.

The actual tests were conducted in the college greenhouse, under a temperature of 72° F, varying a few degrees each way. The bench where the cuttings were planted was covered with fine muslin to provide shade, decrease transpiration and protection from handling. A fine grade of sharp river sand was used as the moisture medium except in the case of the sphagnum moss where both sand and moss were used. Each scion was given a growing space of six square inches and was firmed into the sand by a liberal application of water.

Those set in sand were treated every day for three weeks with their respective chemical solutions, and tap water only was sprinkled on the check tests. During the remaining five weeks they were treated or watered whenever the sand looked dry on the surface. This would be once every other day.

Two kinds of cuttings, terminal and second, were used in these experiments. A terminal cutting is taken from the end of a sprout, leader or lateral branch that has a terminal bud. A second cutting is taken from a sprout, leader or lateral branch after the terminal cutting has been removed. It does not have a terminal bud. Several second cuttings may be taken from one sprout, but only one terminal.

The chemical treatments included solutions of Acetic acid Potassium permanganate, Sucrose, and Thiourea. The concentrations had to be very dilute as strong solutions are toxic. The following concentrations were decided upon after reading the results of experiments carried on by Curtis (1) and Small (6):

1. Acetic acide (1-10,000 solution)
   4.5 cc. per liter of water.
2. Potassium permanganate (.01 molar solution)
   1.6 gr. per liter of water.
3. Pottassium permanganate (1% solution)
   (10 gr. per liter of water).
4. Sucrose (5% solution)
   50 gr. per liter of water.
5. Thiourea (25% solution)
   2.5 gr. per liter of water.

Stronger or weaker solutions would doubtless have altered the results in a marked degree, but whether they would have stimulated or retarded root growth is not known. Time and space prevented the use of variables in this respect.

Records

Complete records of leaf development and root lengths were kept on special mimeographed sheets. One sheet was used for each plot regardless of the number of cuttings it contained.

The various steps in bud and leaf development were recorded under the headings; bud swelling, bud breaking, and leafing. Swelling is used to designate any enlargement or swelling of the bud. Breaking designates a bud which has opened sufficiently to expose part of the green leaf tissue. Leafing means that the buds have opened completely revealing a distinct leaf form.

Root lengths were measured in millimeters and the total number of roots counted when the cuttings were removed from the bench. Water under pressure was used in order to wash the sand from the roots when the cuttings were removed. This facilitated lifting and removing without damaging the roots and root hairs.

PARTICULARS OF EACH EXPERIMENT AND RESULTS

Treatment with Acetic acid, Potassium Permanganate, Sucrose, Thiourea and Water

Green Ash responded differently to each treatment. The Acetic acid plot had twenty cuttings leafed out on March 16, 1927, forty-two days after planting. At this same time the Potassium permanganate plot had thirteen, the sucrose one and the check twelve. When these cuttings were removed from the bench on March 30, fifty-six days after planting, it was discovered that seven had rooted in the Acetic acid plot; three in the Potassium permanganate, none in the Sucrose, and three in the check. The leaves on the cuttings which failed to root had at this time either wilted or were wilting.

Table I — Rooting of Cuttings, Treated with Different Chemicals

Treatment	Green Ash		Soft Maple		Poplar	
	% Rooted	Av. No. Roots Per Cutting	% Rooted	Av. No. Roots Per Cutting	% Rooted	Av. No. Roots Per Cutting
Acetic Acid 1/10.000 Sol.	28	5	100	8.5	96	20.5
Potassium permanganate .01 molar sol.	12	3	28	3	100	13
Sucrose 5% sol.	0	0	12	2	100	10
Thiourea 25% sol. (NH_2CSNH_2)	0	0	0	0	0	0
Untreated check	12	4	84	10	100	18

The number of cuttings that formed callus corresponded closely with the number leafing out in each of the plots. In the Acetic acid plot twenty-one had callused; in the Potassium permanganate eight; in the Sucrose two, and nineteen in the check. All of the

cuttings that rooted had callused, but all that callused did not root.

In these tests the Acetic acid gave a greater stimulating effect on root growth of any other reagent, for by this treatment more cuttings callused, rooted, and leafed out in the Acetic acid plot than in any other, including the check.

Effect on Basswood

No roots were found on cuttings of the basswood, *Tilia Americana*, under any of the treatments. When they were removed from the bench on March 30, 1927, fifty-six days after planting, it was found that ten had started to leaf out in the Acetic acid plot, none in the potassium permanganate, none in the Sucrose and seventeen in the check. Six of the seventeen, however, which leafed out in the check plot had wilted and dried up at the time of removal. It was noted in all species that whenever there were no roots produced the leaves soon wilted and dried up.

Callus formation on basswood had no relation to rooting for the twenty cuttings had heavy callus under the Acetic acid treatment. Nine in the Potassium permanganate, none in the Sucrose and twenty-five in the check, but no roots were found on any of these.

The treatments of basswood produced no positive results and as the check plot showed more vigorous leaf and callus formation than either of the treated specimens, the supposition is that the treatments were harmful rather than beneficial.

Effects on Carolina Poplar

All of the Poplar (*Populus deltoides*) cuttings leafed out with the Acetic acid treatment, and with one exception, they rooted abundantly. With the Potassium permanganate also, all of the cuttings leafed out, but eight wilted and dried up. Nor was the root growth as vigorous as under the Acetic acid treatment. The cause of wilting in the eight cuttings is not known. The solution might easily have been too strong. The tips of some of the roots had started to decay. Poplar cuttings in the Sucrose plot were very unhealthy. All had leafed out but thirteen had dried out. Roots were found on all of the cuttings but they were decayed and emitted an unpleasant odor. The leaf growth in the check plot was very vigorous. They had all leafed out but five were wilted at the time of removal on April 1. Roots were most abundant near the lower end of all the poplar cuttings.

Heavy callus growth was found on all cuttings in every treatment except in those treated with Sucrose. Here the callus growth

had in many cases disintegrated and decayed. In fact the basal ends of some cuttings had begun to decay. Wherever decay had set in the roots appeared well above the decayed portions.

Considering the factors of leaf growth, callus formation, and root growth, the untreated cuttings used as checks gave better results than those treated.

The results obtained with Carolina Poplar are therefore, negative in that the untreated checks produced more roots than those treated.

Effect on Soft Maple

The soft maple (Acer *sacharinum*) rooted favorably in every treatment. Twenty-one cuttings had leafed out under the Acetic acid treatment at the time of removal on April 4; sixty-one days after planting and all of the twenty-five cuttings had rooted.

With Potassium permanganate fourteen had leafed out but two were wilted at the time of removal. Only seven of the fourteen had rooted and their growth was not vigorous. The cuttings treated with Sucrose were very unhealthy. Fourteen had leafed out but the growth was stunted. Just three had rooted and these roots were in a badly decayed condition. The sand in this plot had a very offensive odor which was evidently due to bacterial and fungus action on the Sucrose. Twenty-one cuttings of the twenty-four in the check plot had taken root and twenty-four had leafed out, but these leaves were smaller than those produced with Acetic acid treatment. Callus formation was lacking on all cuttings as far as external appearances were concerned. In fact the basal ends of most of the cuttings were in a state of decay. The roots came out all along the stem. In the check plot they seemed more numerous near the nodes.

The results of this test prove that soft maple may be propagated by cuttings, and that Acetic acid has a stimulating effect on the root growth.

Treatment with Thiourea

This experiment was carried on with cuttings of slippery elm, green ash, basswood, (seconds), poplar, soft maple (seconds) and white oak. The number used in each plot was ten or less. The cuttings were treated with a .25% solution of Thiourea. Thiourea (NH_2CSNH_2) is a compound of sulfur and urea and has extensive use in photography.

The checks contained the same number of cuttings of each species but were moistened with tap water only.

The cuttings were removed from the greenhouse March 19, forty-four days after planting. The poplar and ash had leafed out and then dried out. The rest failed to leaf out. A few short roots were found on the poplar and ash cuttings, but none on the others. These roots, however, were dead. Callus formation was lacking on all.

In the check plot all of the cuttings, with the exception of ash and elm, had leafed out and grew vigorously.

The results obtained by the use of a .25% of Thiourea applied continuously to cuttings were entirely negative as regards both leaf and root growth.

Comparison of continuous and Limited Treatments with Potassium Permanganate

In order to contrast the effect of continuous treatment of a dilute solution of Potassium permanganate with a limited treatment of a more concentrated solution, the following experiment was used.

Cuttings of white oak, soft maple (first and seconds), slippery elm and willow were used, the number in each plot being eleven. Those intended for limited treatment were soaked twenty-four hours in a 1% solution before planting. They were later sprinkled with tap water. The Potassium permanganate plot of the first experiment was used as the continuous treatment. The cuttings in the check plot were soaked in water for twenty-four hours, planted and later moistened with tap water. These cuttings were all removed from the bench on March 21, 1927, forty-six days after planting. In this group the cuttings of maple and willow made vigorous root and leaf growth, both in the limited and check plots. Leaf growth was approximately equal in all plots. Root lengths of cuttings, however, were greater in the limited than in the check or continuous treatments, which indicates that a short time application of a solution, particularly potassium permanganate, gives better results than a continuous treatment.

Growing Cuttings in Potatoes

This experiment was conducted to test the feasibility of a plan mentioned by the late G. B. Sudworth, Dendrologist of the United States Forest Service, in a popular article in the October issue 1920 of American Forestry entitled "Unique example of the propagation of sugar maple from a cutting," wherein it is stated that a large maple tree was grown from a cutting set in a potato in the ground.

Cuttings of all species used in the previous tests were set in potatoes and planted in the sand, and the same number being planted in the sand only for a check plot. Only tap water was used in sprinkling.

All the cuttings set in potatoes, with the exception of poplar, maple and willow failed to leaf out or produce roots. When they were removed on March 21, 1927, forty-six days after planting, it was seen that the roots were growing from that part above the potatoes rather than within the potatoes. The cuttings which did not root or leaf out soon dried out. All of the potatoes had sprouted vigorously. The part of each potato in contact with the cuttings were rotten and none of the cuttings had callused.

The results of this experiment indicate that setting cuttings in potatoes in the sand does not increase root growth.

Rooting Mediums of Sphagnum Moss and Sand

Cuttings of slippery elm, basswood, white oak, willow, soft maple, black walnut, green ash and poplar were planted in equal numbers in sand, sphagnum moss and sand mixed. Ten cuttings or less of each species were used to the plot. A mixture of half sphagnum moss and sand, by volume, was used in one section, sand in the other. Tap water applied in moistening when needed. No other treatment was used.

In these tests oak, elm, basswood and walnut, did not leaf out; and all failed to root except, willow, poplar and elm. This was the only cutting of elm that struck roots in all of the experiments. All of the cuttings except oak, ash and walnut callused. The cuttings in the check plot having a rooting medium of sand, showed leaf growth similar to the species of the other section in every case, ash being the only exception. In this species leaf growth was noticeably less vigorous than in the moss and sand section. Only one ash cutting rooted in the sand. Both the ash and the willow produced more and longer roots in the moss and sand section than in the sand alone. The poplar and ash however, did better in the sand than in the moss and sand. Evidently the moss is a benefit to cuttings of some species only. It is believed by the author that this is caused by either allowing better aeration, or furnishing some plant food, or stimulating root growth by its acid properties. Neither oak, elm or basswood were benefitted by either medium, because they all failed to produce roots.

The results of this experiment indicate that root growth of cuttings of ash and willow are stimulated by planting in a medium

of sphagnum moss and sand, while cuttings of poplar and ash do better in plain sand.

Effect of Maturity of Wood on the Rooting of Cuttings

This experiment was made in order to test value of the maturity of wood in the production and developments of roots. Terminal and second cuttings of green ash, soft maple, poplar and basswood were used. Equal numbers of these scions were included in the treated and the check plots of all the experiments conducted in this project. Thus the tests under this head include those treated with Acetic acid, Potassium permanganate, Sucrose and Thiourea; those planted in sphagnum moss and sand; in potatoes in the sand and the check plots of all these different treatments. Whenever rooting resulted the second cuttings produced larger and better root systems and more vigorous leaf growth than the terminal cuttings. The most reasonable explanation is that the second cuttings, although taken from the same years growth as the terminal scions, contain a greater quantity of stored foid. Zimmerman (7) obtained similar results with cutting of the American pillar rose. Rothacker (6) states that cuttings with a terminal bud always make the best growth. His work was confined to plants and flowers.

The results of this experiment indicate that the maturer wood as it occurs in second cuttings produces better and more abundant roots than the immature wood of terminal cuttings.

SUMMARY

Attempts were made to stimulate root growth on hardwood cuttings by the use of various reagents and by planting in different media. Scions were taken from green ash, basswood, white oak, soft maple, butternut, slippery elm and carolina poplar, planted in sand in the greenhouse. The reagents applied were .01 molar solution of Potassium permanganate; 1/10,000 solution of Acetic acid; 5% solution of Surcose and 25% solution of Thiouea. It was found that the green ash, soft maple, and poplar rooted both with the use of acid stimulants and without, but green ash rooted best with the use of acetic acid, soft maple responded best to Potassium permanganate; Slippery elm (of which one cutting out of ten struck root) did best in spagnum moss and sand. All but soft maple and poplar failed to root when set in potatoes. Negative results were obtained with the use of Thiourea and to a large extent with sucrose. Basswood, white oak failed to root under any kind of treatment.

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