Effects of Some Growth Regulators and Dressings on the Healing of Tree Wounds

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Summarizing the results of a series of 11 studies of tree wounds, the author concludes that lanolin has proved to be consistently effective as a wound-dressing material. Shellac and growth regulators did not promote healing of wounds.

THE WORK here reported was begun in 1942 as one of several series of studies on tree planting and maintenance undertaken at the request of the Camouflage Branch, Army Engineer Board, Fort Belvoir, Va. Under the threat of possible bombing at that time, new buildings at Army posts were being dispersed wherever feasible through wooded areas, and there was much interest in the use of both wild and planted trees for camouflage purposes. Since trees growing in and near the centers of human activity are subject to injuries of many sorts, the Camouflage Branch was concerned with techniques for wound treatment that would promote rapid healing and preserve the life and vigor of the tree.

The field tests were carried out at the Beltsville Experimental Forest, a Forest Service unit of the Agricultural Research Center at Beltsville, Md., with the Bureau of Plant Industry, Soils and Agricultural Engineering cooperating in the planning and technical aspects. Contacts with the Army were through a liaison arrangement between the Camouflage Branch and the Department of Agriculture.

Altogether, 11 separate but related studies were begun during the period 1942-45[1]. In 1946, because of changing emphasis in postwar activities within the Forest Service, and shifts in personnel, the work was drastically curtailed. Only an imperfect record of observations was obtained for the later studies. Ten of the studies were terminated in 1947; for the eleventh, dealing with increment-borer wounds, we hope to make one more examination. This report is a summary of results from the entire series, with many details omitted. Anyone wishing more detailed information is invited to communicate with the author.

Procedures

All the tests were carried out in natural, second-growth woodland on trees ranging from 7 to 20 inches in diameter. Practically every species available in adequate size and numbers was used in one or another of the experiments. The standard test wound, unless otherwise indicated, was an elliptical cut, 3 by 1.5 inches, made with a punch. After making this cut well through the cambium, the wound was cleaned down to raw wood and the bark was bevelled at the bottom for drainage. In every test save one, all chemical treatments involved were applied on each tree. Where many wounds were required, they were arranged in a spiral or staggered pattern around the trunk so as to leave several inches, both laterally and vertically, between wounds.

The first 6 of the 11 studies were started in the fall of 1942. Study I was mainly a test of several kinds and concentrations of growth regulators in two carriers—lanolin and orange shellac—plus untreated controls. Included also were two other chemical treatments in the same carriers—traumatic acid, a wound hormone first isolated from string beans, and a mixture of sugar, yeast, and nutrient mineral salts. The growth regulators were indoleacetic, indolebutyric, naphthaleneacetic, and naphthoxyacetic acids, and naphthalene acetamide. Concentrations varied from 0.1 to 4.0 percent. Total number of wounds per tree was 32. Other experimental variables were season of wounding (fall, winter, and spring), immediate vs. delayed treatment of wounds, shading with cloth vs. no shading of wounded trunks, and seven tree species—red maple, black gum, beech, white oak, scarlet oak, pitch pine, and Virginia pine. Each ultimate wound series was replicated on three trees. Total number of trees involved was 252.

Studies II to V were compartively minor experiments designed to supplement certain aspects of Study I. They will be briefly explained as the results are discussed later.

Study VI was a test of the effect of mineral fertilizers in conjunction with growth-regulartor treatments to stimulate wound healing. There were 12 wound treatments per tree, consisting of control, shellac on the edge plus plastic asphaltum on the wood face, and 10 treatments composed of varying amounts of growth regulators in lanolin. The soil fertilizers comprised three levels of nitrogen, each of which was combined with three levels of phosphorus and potassium. These were broadcast under the tree over a circular area, the size of which was determined by a radius in feet equal to 1.5 times the trunk diameter at breast height in inches. The three levels of N were 0, 125, and 375 pounds per acre; for P_2O_5 and K_2O, the three levels were respectively 0-0, 150-80, and 450-240 pounds per acre. Two seasonal series (December and April) were installed on two species—white oak and pitch pine. With nine fertilizer treatments, and the ultimate sets replicated on three trees, total number of trees involved was 108.

[1] A number of people participated in these studies. Dr. C. L. Hamner, then of the Bureau of Plant Industry, Soils and Agricultural Engineering, and Dr. E. J. Kraus of the University of Chicago, then serving part-time with the same bureau, were responsible for planning the growth-regulator treatments and the technical aspects of their application. For the Forest Service, T. E. Maki, of the Northeastern Forest Experiment Station, was in charge and took an active part during the first 2 years; Dr. Elbert L. Little, Jr., planned and supervised some of the earlier installations; and Dr. Carl E. Ostrom assisted at times in the statistical aspects. Most of the field work was done by men from Civilian Public Service Camp 34. One of these, Joseph W. Showalter, was responsible for all routine field work, summarization of data, and preparation of progress reports up to the time of his discharge. His work is especially commended.

Study VII was a test of several lanolin admixtures and other combinations as wound dressings. The idea of lanolin admixtures stemmed from the observation in earlier studies that lanolin possessed desirable properties as a dressing and that, when applied to wounds on pines, those properties seemed to be enhanced by the incidental blending with exuding pitch. The test series consisted of lanolin alone, lanolin with crude pine gum, with linseed oil, with turpentine, with rosin, with rosin plus finely ground charcoal and mineral nutrients, with rosin plus 0.75 percent tryptophane, with 1 percent propionic acid, lanolin on the edges plus overcoating of entire wounds with Bordeaux paste, lanolin on edges and overpainted with asphaltum, orange shellac on edges and overpainted with asphaltum and two untreated controls, making 13 wounds per tree. The tests with tryptophane, a chemical allied to the growth-regulator group, and propionic acid, a mold inhibitor, were included as ''long shots'' at the suggestion of Dr. Kraus. The treatments were replicated three times on three species (white oak, scarlet oak, red maple) three seasons (July, November, March), and two exposures (north and south), requiring 54 trees altogether.

Study VIII, started in 1944, was an extension of Study VII. It included two phases—a weathering test of 140 different experimental formulations, all but 10 of which contained lanolin, and second, a test of 25 of these formulations on freshly made wounds on three white oak trees. The formulations were various combinations and proportions of lanolin, rosin, beeswax, tallow, linseed oil, paraffin, crude pine gum, cod liver oil, asphaltum, lamp black, and infusorial earth. The weathering tests were made in simulated wounds on three board panels placed under different exposure conditions in the woods.

Study IX, also started in 1944, extended the investigations to pruning wounds; all previous tests had been on wounds systematically placed on the tree trunks within reach from the ground. The treatments consisted of shellac alone over the entire wound, shellac overpainted with asphaltum, shellac overpainted with lanolin-rosin (proportions 100-40), lanolin-rosin alone, lanolin-rosin plus finely ground charcoal, and lanolin-rosin plus mixtures of four growth regulators in total concentrations of 0.01, 0.05, and 0.15 percent. With a control, this made 9 treatments. These were applied to three species (white oak, pin oak, and sweet gum) in two seasons (March and September). The wound treatments were divided into two series, each of which was installed in duplicate on each of six replicate trees. Total number of trees used thus was 72. Only wounds from pruning live limbs were used in the tests. In general, wound sizes were held within the range of 1 to 3 inches in diameter.

Study X, started in 1944, consisted of two rather simple experiments to determine the ability of trees to form callus directly on the face of wounds. This type of healing had been described by Fenner (*1*) and sporadic instances of it had been observed in our work. According to Fenner, the basic requirements are shade and living cambium on the face. He advocated efforts to induce this type of healing in shade-tree wounds when the cambium remained more or less intact after the injury.

The first experiment was a comparison of all-over dressings of lanolin and shellac, shellac only on wound edges (Fenner's recommendation), and no treatment, on wounds where the cambium remained largely intact over the wound face. The wounds were 3 by 6 inches, elliptical in shape, and all placed on the north side of the trunks. No additional shading was provided. These four treatments were replicated on three white oaks. The second experiment, in 1945, consisted of two pairs of 3- by 6-inch elliptical wounds per tree, one pair shaded with cloth, and one unshaded. The cambium was left on all wound faces. One wound of each pair was shellacked on the edges (Fenner method), the other dressed all over with lanolin. Eight trees—4 white oaks and 4 red maples—were so treated. The wounds faced west on half the trees and east on the others.

Study XI, started in the fall of 1944 and not yet concluded, deals with the wounds made by use of an increment borer. All test wounds were 4 inches deep. The following 10 treatments were used: (1) untreated control; (2) hole tightly plugged with a black locust dowel; (3) same as 2 except the hole and dowel were first disinfected by swabbing with 0.1 percent mercuric chloride solution; (4) plugged with lanolin-rosin-asphaltum in proportions 1-1-2; (5) same as 4 except hole was first swabbed with mercuric chloride solution; (6) plugged with lanolin-Bordeaux powder in propotrions 10-2; (7) injured bark trimmed around wound to diameter of about 1 inch and dressed with lanolin-rosin in proportions 10-4, inner hole not plugged; (8) same as 7 except hole was first swabbed with creosote; (9) plugged with commerical puttirope; (10) same as 9 except hole was first swabbed with mercuric chloride.

Three species, *viz.*, white oak, red maple, and sweetgum, were treated in October, March, and June. Three additional species—yellow-poplar, beech, and river birch—were treated only in October and March. Three replicate trees were treated each time. One extra tree of each species was treated in October for early felling and dissection. Total number of trees used was 51. The extra trees above mentioned were taken out in October 1947 and their condition is discussed below. The remaining trees still stand. If circumstances permit, some or all of these will be felled and dissected at a later date, and the study will then be formally concluded.

All together in the 11 studies, 646 trees were used, most of which had a dozen or more wounds. The total number of wounds involved was 13,560.

Results

Tree wounds heal mostly from the sides. Consequently the most important single measure of healing is the amount of lateral closure, or its reciprocal—the width of wound face remaining open. The latter is easily measured with an inside caliper, and this was the basis for most of the comparisons in this study. Various other observations were made and considered in the final evaluations. Among these were initial die-back (laterally and vertically), vertical closure, condition of dressing, checking of wound face, and presence of molds or insects. The rather voluminous field data were summarized and analyzed statistically from time to time as seemd necessary for interpreting current developments.

The statements of results appearing below, although made with little elaboration or explanation of the exact basis for their acceptance, are founded upon careful examination and analysis of a great mass of data.

In the first study, the 32 wounds per tree were arranged in two spirals extending from 1 foot to 7 feet from the ground, and encircling the tree twice. Two questions arose in using this design: (1) Would the tree be so severely injured by this number of wounds that it could not respond normally to the wound treatments? and (2) With the spacings used, would a given wound be effected by growth-regulator chemicals applied to a neighboring wound? The supplemental studies numbered II to V were made to provide some information on these uncertainties.

In one experiment, intensities of wounding varying from 16 to 128 wounds per tree within the 1- to 7-foot height zone showed that the 32 wounds per tree in Study I was a safe intensity. Double that number apparently could have been tolerated without loss in healing response. One tree in four with 128 wounds died; the other three showed no decline in vigor. Another experiment carried the intensity theme to the limit—the trees were completely girdled by two continuous spirals corresponding to the pattern of wound placement in Study I. Vertical translocation of solutes in the phloem thus could take place only by following the course of bark between the spirals. Here 7 of 14 test trees died. Red maple, black gum, and beech withstood this type of girdling better than the oaks and pines. These results, however, did not affect the acceptance of 32 as a safe number of wounds for experimental work.

Two experiments were made to ascertain whether growth regulators were translocated from the place of application, i.e., whether treatment of one wound with these substances would affect neighboring wounds. The tests were done by treating certain wounds in variously spaced and variously arranged groups, and observing effects on all wounds in the group. Some evidence of growth regulator translocation was obtained, but the results as a whole were not conclusive. Effects, if any, of growth regulators applied on another wound 2 inches or more distant were erratic and generally not significant.

Results and conclusions as regards the major aspects of the studies were as follows:

Growth Regulators and Other Specific Chemicals

The growth-regulator chemicals as applied in wound coatings were definitely injurious in the higher concentrations used; at lower concentrations (0.1 percent and less) their effects were inconclusive. No growth-regulator treatment was found that significantly increased the rate of wound healing in any tree species. Likewise, none of the other specific chemicals tested was beneficial.

Dressings

Shellac consistently was a poor treatment in these tests; wounds so treated healed only slightly better than controls.

Lanolin alone, and in blends with rosin and pine gum, were good dressings. The beneficial effects came mainly from the protection of the wound edges against drying and resultant die-back. With this protection, callus forms at the wound edge; without it, the cambium and phloem die back as much as an inch or more under the bark, and healing must start from there. Moreover, during the period of dying back there can be no differentiation of callus from the phloem and cambial tissues and no start toward healing. The more rapid closure of lanolin-treated wounds thus was due primarily to the prevention of wound enlargement and to prompter initiation of callus growth. However, lateral growth of callus after its initiation also tended to be slightly faster on lanolin-dressed wounds than on untreated controls. In a comparison involving 45 trees divided among 5 species, this increase in callus growth for 1 year averaged 14 percent. This is not great enough to be of much significance on small wounds, but if it could be maintained on larger wounds it would be a worth-while advantage.

In physical properties, blends of lanolin and rosin in proportions of about 10 to 4, or lanolin-rosin-pine gum in proportions of 10-2-2, were superior to lanolin alone. The blends were more elastic; they tended to form a film that remained intact remarkably well as the topography of the wound area changed during development of the callus, and they were workable over a fairly wide range of temperatures. Lanolin alone was more sticky, less pliable over an expanding callus, and more sensitve to temperature. On very warm days fresh lanolin in the sun would melt and run. Healing under lanolin alone and under its better-appearing blends was essentially the same except where melting and runoff had occurred.

Plastic asphaltum over shellac did not give the physical appearance of a good dressing: it became brittle and cracked or curled away from the wood after a few months. However, healing under this dressing compared favorably with that under lanolin. Evidently the shellac-asphaltum combination provided good protection during the crucial period prior to callus differentiation, and deterioration later made little difference.

Bordeaux paste (Bordeaux powder and raw linseed oil) over shellac was not a satisfactory dressing. It soon became brittle and cracked. Moreover, it is likely to be toxic to the cambium.

The weathering test of dressing materials (Study VIII) failed in its original purpose. Most of the substances, except those that melted and ran, still were in good condition after 4 years' exposure. However, as became increasingly evident after the weathering test was set up, deterioration of dressings on live wounds is in large part induced by changes in wound topography during the die-back and healing processes, and by exudations that may diffuse into the dressing, loosen it from the wound surface, or affect it indirectly by fostering the growth of molds and bacteria. Mere weathering seems to be of secondary importance. Hence durability on the exposure panels did not prove to be a good measure of durability in actual service.

Tree Species

Very striking differences in rate of healing were found between species. White oak was consistently the fastest healer among the species used in these tests. It usually suffered relatively little die-back at the wound edges, and callus growth was relatively rapid. With the better treatments, many of the standard 1.5- by 3-inch wounds closed in one year, and a majority under all treatments were closed at the end of two years. Black gum behaved similarly, with little die-back and with callus growth almost as rapid as in white oak. Red maple was one of the slowest hardwoods to heal, mainly because it usually underwent excessive die-back. Its tendency to bleed reduced the efficacy of dressings. Callus growth, when established, was reasonably rapid, but often a year or two more were required for the callus to recover the area lost by die-back, thus greatly prolonging the time required for the wound to close completely. Scarlet oak was also subject to considerable die-back, and hence rather slow to heal. Beech did not die back severely but was a slow healer simply because of slow callus growth. Pin oak, observed only in the pruning-wound study, healed fully as vigorously as white oak. Sweetgum in the pruning study was more subject to vertical die-back, but otherwise was a relatively rapid healer.

The pines were notoriously slow to heal, solely because of slow callus growth. Because of pitch exudation in the wounds, there was little die-back and no evidence of fungus infection. After 2 years, the wounds on Virginia pine had not healed enough to warrant measurement; on pitch pine the original wound widths for all treatments had been reduced, on the average, about 30 percent.

Season of Wounding

In general, with the exception of red maple, wounds made in late winter or early spring healed faster than those made in the fall or late spring and summer. Red maple wounds healed best when made in late spring or early summer (May-June). In this species, healing apparently is retarded in early spring wounds because of excessive bleeding.

Orientation and Height of Wounds

Fall wounds seemed to heal better if facing south, whereas spring and summer wounds healed better when on the north or shaded side of the trunk. Among series of wounds on the same tree, the lower ones tended to heal better than the upper ones. These are apparent tendencies of minor importance; they are not offered as definite conclusions.

Fertilizer and Tree Vigor

Considerable variation in rate of healing occurred between trees of the same species, presumably due to differences in vigor. Increase in growth vigor through applications of fertilizer might therefore be expected to increase rate of wound healing. This effect was obtained in white oak. Two years after treatment, increases in growth rate, determined from increment cores, ranged from 0 up to 86 percent among the nine fertilizer combinations. Statistical analyses showed that the growth responses were influenced more by the amount of nitrogen than by phosphorus and potassium. The rate of healing likewise was accelerated by the fertilizer treatments (up to a maximum of 66-percent increase over no fertilizer) on trees receiving the high level of nitrogen with the intermediate level of phosphorus and potassium. As with diameter growth, nitrogen was the most influential element.

Pitch pine—the other species in the fertilizer experiment—was less responsive. Small statistically significant increases in diameter growth were induced by fertilizers, but differences in wound healing were not significant.

Surface Callus

Proliferations of tissue on wound faces occurred sporadically in several of the experiments. Whether these developed from wood-ray cells or from remnants of cambium was never positively determined. Though most such surface growths died out within a few months, occasional ones developed a periderm with a green cambium-like layer beneath, and became a permanent part of the callus overgrowing the wounds.

In the two small experiments set up under Study X to test possibilities for inducing surface callus to form, the first (on three white oaks, no artificial shade) yielded some temporary proliferations but no permanent tissue. In the second experiment (4 white oaks, 4 red maples, with and without artificial shade), five of the total of 32 wounds exhibited areas of living surface callus ranging from 30 to 80 percent of the wound face 2 years later. Seven other wounds had sizeable areas of surface callus that appeared to have died. Callus formation was scattered among the treatments on both species; no condition stood out as markedly more favorable than others for such growth. Considering that the cambium was left over the entire faces of these wounds, and other conditions were as favorable as was known how to provide, the prospects for inducing formation of permanent surface callus in any substantial proportion of accidental wounds seem rather remote.

Pruning Wounds vs. Wounds on Clear Bole

Except for some first-season observations, no data on healing of the pruning wounds were obtained until the fall of 1947. The March installation had then gone through four summers, and the September installation through three. Of the 432 wounds in the dressings series, 248 (57 percent) had closed. At this late stage, width-of-callus measurements had lost much of their value because they did not distinguish between the varying lengths of time required for different closures to take place. Sensitive treatment comparisons therefore were impossible. The best remaining basis for comparisons was numbers of wounds closed, which—expressed in percents (species and seasons combined)—were: untreated controls—49, shellac alone—43, shellac plus asphaltum—65, shellac plus lanolin-rosin—68, lanolin-rosin alone—64, and lanolin-rosin-charcoal—58.

By this criterion, shellac alone showed no benefits, whereas the other four dressings all apparently increased rate of healing. Mean percent closed for the latter four dressings is 64, as compared to 49 percent for controls. Taking closures of controls as a base, this difference of 15 percent represents about a 30-percent increase in closures due to dressings.

Pruning wounds and clear-bole wounds showed the same general reactions to treatments, i.e., healing the best under lanolin or asphaltum dressings. Shellac coatings alone were of little or no value, and no beneficial effects were obtained from growth regulators. Pruning wounds, however, healed somewhat more slowly, probably because of the slight protuberances that remained even after careful flush pruning. White oak, the only species common to both the pruning and other studies, furnishes the best measure of this difference in healing rate. White oak pruning wounds of the March installation averaged 2.06 inches wide, and most of them were closed after four summers. Thus they closed laterally at approximately 0.5 inch per year. In other studies, similarly treated clear-bole wounds 1.5 inches wide closed to about the same extent in 2 years, or at a rate of 0.75 inch per year.

Though no definite comparative data are available, pruning wounds obviously were more subject to infections, as evidenced by wet-wood and slime-flux conditions. This doubtless was related to the presence of heartwood in some pruning wounds. Where such infections occurred, healing was much retarded. Of 31 badly infected pruning wounds noted, 15 were untreated, 7 had been shellac-coated, and 9 were distributed among the other 7 treatments. From this it may be inferred the lanolin and asphaltum dressings provided some protection against infection as well as against drying and die-back of the wound edges.

Increment Borer Wounds

Dissection of the six trees removed in 1947 (three growing seasons after wounding) revealed some evidence of incipient wood decay, notably in red maple, red gum, and beech, but no correlation of decay conditions with treatments was discernible. All but 4 of the 60 wounds examined were closed. All species except white oak showed more or less staining in a vertical strip upward and downward from the wound, as described by Hepting et al (*2*). The deep blue-black stain formed in yellow-poplar was particularly striking.

In view of Hepting's statement that the birches (paper, sweet, and yellow) underwent more extensive discoloration than any other species in their experiments, the behavior of river birch in our tests is of interest. All 10 wounds on the one river birch dissected were closed; there were no cankers, no obvious rot, and the stain was less conspicuous and less extensive than in any of the other five species except white oak.

In general, however, our preliminary observations are in accord with Hepting's report. Though the incidence of cankers was lower among our trees, we found the same general types of discoloration, and the same failure or plugs or wound treatments to prevent the undesirable after-effects of increment boring.

Discussion and Conclusions

Chief among the general conclusions to be drawn from the wounding studies are these: (1) That wound treatments do not greatly alter the rate of callus growth; and (2) that a main function of a wound dressing is to prevent drying and resultant die-back, thereby facilitating early differentiation of callus at the wound edge. A second function of a dressing, not much explored in these studies except in increment-borer wounds, is to prevent infection. Differences in rate of healing, other than those due to species or tree vigor, come about mostly from differences in the amount of die-back or wound enlargement, and the correlated differences in time required for the dying-back to run its course and permit callus differentiation to take place. Once callus has been initiated, its rate of spread over the wound face may be almost or fully as fast without dressings as with them—so long as no other factors come into play. Spread of callus may be retarded, however, by toxic chemicals in a dressing, or by slime flux from an infection.

In the literature on tree wound treatment, shellac has been reported in several instances as one of the most effective dressings. Without reviewing the subject, Nank's study (*3*) may be cited as an example. Comparing shellac, Bordeaux paste, and three trade-name dressings on wounds of English elm, his shellac-treated wounds healed best of all. Contrary to this and other reports, our shellac-treated wounds consistently healed little or no better than untreated controls, and definitely more slowly than those coated with lanolin or asphaltum. The reason for this discrepancy is not apparent. Our shellac was freshly prepared by dissolving the dry orange flake lac in alcohol. That used in the first studies contained 20 percent flakes by weight; in later work the proportion was increased to 40 percent, but with no marked difference in effect upon healing.

Probably the most important result of this work was that it demonstrated the potentialities of lanolin as a base for tree-wound dressings. Very few references to lanolin are to be found in the literature and no commercial dressing is known to the writer that contains lanolin as a basic ingredient.

The first published mention of lanolin as a wound dressing is believed to be in a paper by Shear (*5*) in 1936, in which he reported it as beneficial, and superior to white lead paint. In 1940, however, Tilford (*6*) reported some apparent cambial injury from lanolin, and poorer healing than with asphaltum. In 1945, a brief report (*4*) on some phases of the present work was published, in which the beneficial effects from use of lanolin and certain lanolin blends were pointed out. Subsequent results serve only to confirm further that earlier report. The performance of lanolin, both alone and in blends with rosin and pine gum, has been so consistently good in these experiments as definitely to establish a place for it among proved wound-dressing materials. In retention of plasticity it is much superior to asphaltum. Lanolin-rosin blended in proportions of 10 to 4 is suggested as a basic mixture. The viscosity of this can be increased by adding beeswax, or decreased by adding crude pine gum. Blending is done simply by mixing the substances together in a melted state.

It should be recognized in evaluating these studies that the test wounds were relatively small, that most of them were on sapwood and therefore less susceptible to infection than where heartwood is exposed, and that no comparisons with trade-name wound dressings were made. Hence the value of lanolin, though well demonstrated on the small wounds, remains to be confirmed for larger heartwood wounds. Painting heartwood wounds with shellac as a sterilization measure before applying lanolin, as was done in the pruning study, will likely prove to be a good combination. The efficacy of antiseptic substances incorporated into lanolin mixtures should be investigated. These dressings should be compared with various trade-name preparations on a wide range of species. Only then will the general utility of lanolin as a dressing material be fully determined.

Summary

1. A series of 11 studies dealing with treatments to promote healing of tree wounds is described. The treatments involved several substances used as dressings, with and without incorporation of growth regulator and other chemicals. Other variables were tree species, soil fertilizer applications, season of wounding, intensity of wounding, orientation and shading of wounds, and kinds of wounds. Altogether, 13,560 wounds, distributed over 646 trees representing 10 species, were made and observed.

2. None of the growth regulator or other specific chemicals significantly increased the rate of wound healing in any tree species.

3. Dressing the wounds with lanolin promoted healing by preventing drying and die-back, thereby allowing callus to form promptly at the wound edges. The physical properties of lanolin dressings were improved by incorporation of rosin and pine gum.

4. Good healing also occurred in wounds painted with shellac and overcoated with plastic asphaltum. Shellac alone was ineffective in promoting healing. As a dressing, Bordeaux paste was inferior to both lanolin and shellac plus asphaltum.

5. The tree species varied greatly in rates of healing and susceptibility to die-back from wound edges. Of the 10 species used in these experiments, white oak was the fastest healer, and Virginia pine was the slowest. Red maple wounds often were long in closing because of excessive die-back.

6. Within a species, rate of healing seemed to be correlated with tree vigor. Healing rates were significantly increased in white oak by applications of fertilizer to the soil.

7. Except on red maple, wounds made in late winter or early spring healed faster than those made at other seasons. Because of excessive bleeding in early spring, wounds on red maple healed best if made in late spring or early summer.

8. Callus sometimes developed directly on wound faces from ray cells or fragments of cambium. Attempts to consistently induce the formation of such callus were unsuccessful.

9. Pruning wounds and wounds on the clear bole healed and responded to treatments in much the same manner, except that pruning wounds tended to heal somewhat more slowly.

10. Three seasons after boring, most increment-borer wounds on six hardwood species were closed externally, but no treatment tested had been effective in preventing discoloration of the wood. Not enough time had yet elapsed since boring to reveal correlations, if any, between treatments and wood decay.

Literature Cited

1. FENNER, CARL. 1942. Shade method of direct cambium-to-bark development. Natl. Shade Tree Conf. Proc. 18: 131-138.
2. HEPTING, GEORGE H., ELMER R. ROTH, and BAILEY SLEETH. 1949. Discolorations and decay from increment borings. Jour. Forestry 47: 366-370.
3. NANK, EDWARD. 1949. Effects of pruning and wound dressings upon callusing. Arborists's News 14:1-5
4. MCQUILKIN, W. E. and J. W. SHOWALTER. 1945. Lanolin mixtures as dressings for tree wounds. Arborist's News 10:17-19.
5. SHEAR, G. M. 1936. Lanolin as a wound dressing for trees. Proc. Amer. Soc. Hort. Sci. 34: 286-288.
6. TILFORD, P. E. 1940. Tree wound dressings. Natl. Shade Tree Conf. Proc. 16: 41-53.