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Wound Dressings on Apple Trees

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INTRODUCTION

The treatment of pruning wounds of fruit and other trees has been of interest to orchardists and other plantsmen for many years, and as a result many different types of wound dressings have been devised. In an endeavor to prevent certain diseases of which the causal organisms enter through wounds, such as those of the canker type, plant pathologists have prepared and studied wound dressings and have recommended various treatments. Most of these have, however, had some decided shortcomings.

A study of wound dressings for woody plants and of their effects on wound-inhabiting parasites and on the hosts involves many phases of the physiology of the wounded and treated plants. The widespread use of wound disinfectants in animal surgery has possibly had its influence on the use of wound dressings on plants. However, the wound reactions of plants and animals differ in many respects, and erroneous conclusions may follow from presumed analogies.

One of the most important aspects of the pruning-wound problem is the fact that until completely callused over, a wound remains unprotected from checking and weather influences and is susceptible to attack by fungi that cause wood rots. Rapid healing of pruning wounds and the lasting qualities of any dressing used are therefore important. The readiness with which a wound heals is correlated with such factors as the general vigor of the tree, the amount of leaf surface above the wound, the nature of the wound dressing applied, and the time of the year when the wound is made.

[1] Grateful acknowledgement is here given to Jesse H. Crenshaw, formerly agent in this Division, for help on the part of the work carried on at Hood River, Oreg.

The ideal dressing should be noninjurious to cambium and should protect the exposed wood against decay-producing organisms during the several months required for healing. It should not melt and run in summer or become hard, crack, and flake in winter; it should adhere to fresh wounds and be easily applied; and it should be sufficiently porous to let excess moisture evaporate from the wound beneath it. For use in connection with certain diseases, the ideal dressing should be toxic to the causal organism but should not injure the host. For example, while working with the fungus that causes a killing disease of planetrees and sycamores, Walter and Mook (*15*) [2] found that asphalt dressings that killed the causal fungus also killed the cambium and that certain asphalt dressings were not antiseptic and might transmit the causal fungus.

This circular reports studies on the development and evaluation of wound dressings and the effects on callus formation of a number of different types of wound dressings applied to fresh wounds on apple trees and also of the effect of season of wounding upon the healing of the wounds. An attempt was made to discover treatments that did not kill the cambium around the wounds on apple trees and thus enlarge them and to learn the time of year when apple tree wounds form callus most readily. The work was begun in connection with studies on the perennial canker of apple trees, caused by *Neofabraea perennans* (Zeller and Childs) Kienholz. It was carried on at Hood River, Oreg., from 1929 to 1931 and was continued from 1931 to 1938 at Arlington Experiment Farm, Arlington, Va.

REVIEW OF LITERATURE

The literature on wound dressings indicates that their use has been aimed principally at preventing the entrance of disease-producing organisms at wounds.

Brooks and Moore (*2*) showed that it was very difficult to prevent invasion of the silver leaf organism by an application of a fungicide to the wound. They tested many old preparations and also devised a number of new ones, but their preparations usually either did not kill the pathogen or killed too large an area on the treated plant. Brooks (*1, p. 272*) finally recommended soft grafting wax or a white-lead paint.

Howe (*8*) investigated the healing of apple tree and peach tree wounds treated with shellac, white lead, yellow ochre, white zinc, and avenarius carbolineum. He reported impaired healing with all treatments except shellac and stated that many of the commonly used dressings did more harm than good because of their toxic effects. He obtained nearly as good healing where shellac was used as where the wounds (check) were unpainted.

Zeller (*16*) recommended bordeaux paint made by stirring raw linseed oil into a commercially prepared bordeaux dust. He contended that one of the chief advantages of this dressing is that it is sufficiently porous to allow evaporation of the exuded sap.

The early literature on wound dressings was reviewed by Marshall (*9*), who reported that wounds on certain forest trees healed better if given a coat of shellac than if left untreated. His work also em-

[2] Italic numbers in parentheses refer to Literature Cited, p. 18.

phasized the differences in callus growth of the trees when trunk wounds were made with an auger at different seasons of the year; the healing was more rapid on wounds made in the spring than on those made at any other season. Rose (*11*) also reported that callus formation was better and injury less on wounds made in the spring than on those made at any other time.

The work of Swarbrick (*13*), using sycamore, rhododendron, apple, and plum, though not concerned directly with wound dressings, helps to interpret the work reported herein. He showed that severing a branch of about ¾-inch diameter, probably containing living cells throughout its cross section during the growing season, May to August, causes rapid disappearance of starch from the cut end, followed by development in the vessel cells of a viscous substance, which apparently blocks them. Wounds made in September and October are only partly plugged and remain that way throughout the winter, whereas those made from November to March, or in the dormant season, show no plugging until growth activity begins in May, at which time starch begins to disappear and gumlike substances develop. Blocking may be completed in 4 to 6 weeks from the beginning of starch disappearance. Swarbrick's work indicates that the accumulation of the resinous substances may result in differential penetration and killing by slightly toxic wound dressings applied at different seasons of the year.

Cope and Spaeth (*5*) demonstrated that sodium arsenite was more lethal when applied to tree wounds in the fall than when applied in the spring.

Tilford (*14*) reviewed the recent work on wound dressings and reported experimental work on a number of different dressings on forest trees. Liquid asphaltum accelerated healing on most of the species treated. Other treatments in general produced healing comparable with or poorer than that on the checks.

Walter and Mook (*15*) showed that the *Ceratostomella* that causes a canker of the planetree may be carried by infected sawdust in wound dressings.

Many wound dressings containing a wide range of constituents have been recommended by various workers. Very few of the recommendations, however, appear to have been based on adequate experimental evidence, and most of the dressings recommended have not become generally used.

DEVELOPMENT AND PRELIMINARY EVALUATION OF WOUND DRESSINGS

While attempts were being made to devise a wound dressing having the desired properties, a large number of preparations reported in the technical literature or by some plantsmen as having merit were tested. Among the preparations tried were several types of grafting wax, an asphalt-creosote mixture, paints containing metallic copper in finely divided form, bordeaux dust in linseed oil, and Day's (*7*) mixture of zinc chloride, alcohol, and hydrochloric acid. All these preparations were found to have some decided draw-back.

In endeavoring to compound a wound dressing possessing the desired properties, many different materials were used either alone or in various combinations and in various proportions. Mixtures of asphalt, beeswax, pine gum, paraffin, japanese wax, spermaceti, cocoa butter, and rosin were used in combination with the following carriers: Spray oils, castor oil, drying and nondrying fish oils, linseed oil, petrolatum, transmission oil, hydrogenated fat, cottonseed oil, rapeseed oil, crude petroleum, and glycerin. These were applied while warm or thinned with gasoline, kerosene, turpentine, ethyl or methyl alcohol, acetone, Varsol,[3] and Bayol.[3]

Of the various materials tried, the best dressings were made by a combination of rosin and fish oil. Such a dressing was also used for the incorporation of the following substances expected to have disinfecting properties: Copper sulfate, bordeaux mixture, sulfur, paris green, copper soap, and copper resinate. Of the large number of materials used in one way or another, copper soap seemed to be the most promising to combine with a wax [4] containing rosin and oil.

Other chemicals not miscible with the previously mentioned waxlike dressing were used in water and kaolin or in a water emulsion. The following were so used: Mercuric cyanide, mercuric chloride, sodium chromate, zinc chloride, cresylic acid, picric acid, and creosote.

More than 500 combinations of the various ingredients were made, many of which were tested by application to pruning wounds and wounds resulting from excision of cankers. Others were discarded without testing because of evident unsuitableness. Most of the substances had decided draw-backs. Some were so thick that they prevented proper aeration and drying of exuded sap and thus resulted in water blistering, a condition also noted by Marshall (*10*). Other dressings soon crumbled off under the influence of weathering agents. Still others, such as oil and lead paint, made a hard, continuous covering, and callus growth soon produced cracks that provided shelter for the woolly apple aphid (*Eriosoma lanigerum* (Hausm.)). The application of such substances as paraffin resulted in callus growth that was abnormally susceptible to winter injury.

Many coverings containing an active disinfectant were abandoned because they killed the tissues surrounding the wound. In some cases the solvent that was used caused killing, particularly on fresh wounds. Sometimes uncombined oils caused injury, especially when applied during the autumn.

Two of the large number of dressings tested in the Hood River Valley, Oreg., No. 540 and No. 541, seemed most promising and were later used at Arlington Experiment Farm, Arlington, Va., in comparison with other dressings, in the study of callus behavior.

Dressing No. 540, containing a disinfectant, was made by the following formula by weight:

Rosin (H or I grade)	7 parts
Sardine oil	3 parts
Copper soap	3 parts

Dressing No. 541, which appeared to be the best of all wax-type dressings, differed from No. 540 mainly in the omission of the copper soap. It contained by weight:

Rosin	8 parts
Sardine oil	3 parts

[3] Supplied for test by the courtesy of the manufacturer.

[4] In chemical literature, wax is used to designate a group of substances having a definite chemical structure, the most familiar being beeswax. In this circular, however, the term "wax" is used to designate compounds having certain waxlike physical properties, but not necessarily conforming to the chemical definition of a wax.

Dressing No. 540 was prepared by heating the rosin with the sardine oil until the rosin melted, then cooling until the addition of a few drops of water caused no spattering, and then adding the soap, which was mixed in by stirring and cautious heating until the wax was a homogeneous mass. Dressing No. 541 was prepared by heating together the rosin and the fish oil.

Copper soap may be purchased from a marine products or chemical supply company, or it may be made as follows: Dissolve 1 pound of potassium hydroxide in 1 quart of boiling water, add slowly 5½ pounds of fish oil while stirring vigorously, and continue heating until a smooth soap is formed; dilute with ½ gallon of water and add 2 pounds of copper sulfate dissolved in ½ gallon of hot water; continue heating until the copper soap separates out and the liquid has lost most of its blue color. When cool, decant the liquid. This should leave not more than 12 pounds of soap. There is a great difference in the saponifying properties of different fish oils. Salmon oil has proved very satisfactory.

Many of the substances and combinations used in the experiments reported are poisonous. Therefore potential users unfamiliar with them should ascertain their toxic properties and store their stock supplies or dispose of surplus mixtures where they will be out of reach of children and animals.

EXPERIMENTAL TESTS OF DRESSINGS

Materials and Methods

Early in the study of wound dressings differences were found in injuries caused by dressings of the same formula but made and applied at different times. Later, it was noted that the same batch of material caused different amounts of injury when applied at different seasons of the year. In November 1930 experiments were started to obtain more information on the effect of the seasonal-growth cycle on treated wounds and on callus formation and to determine the effectiveness of a fungicide in a wound dressing.

At Hood River, Oreg., wound dressings were applied immediately or at definite later periods to pruning wounds made in early spring during the usual pruning operations on apple trees. Also apple trees were wounded and treated at different times during the year. The work was later repeated at Arlington Experiment Farm, Arlington, Va.

All the apple trees used, in both Oregon and Virginia, were more than 20 years old and lacking in vigor. They were named varieties, but as variety was considered unimportant, results for all varieties were combined. The trees developed callus very slowly, and the least vigorous ones were more injured by slightly toxic dressings. Such weak trees are the type on which develops the most trouble in pruning wounds in general orchard practice.

All the wax preparations were applied at the consistency of a thick paint, this being obtained either by warming with a grafting lantern or by diluting with a solvent such as gasoline. The preparations used were (1) dressing No. 540 (p. 4), (2) dressing No. 541 (p. 4), (3) white lead and raw linseed oil as a thick paint, (4) No. 540 with gasoline as a thinner, (5) No. 541 with gasoline as a thinner, and (6) shellac. During the first year at Arlington Experiment Farm supplemental

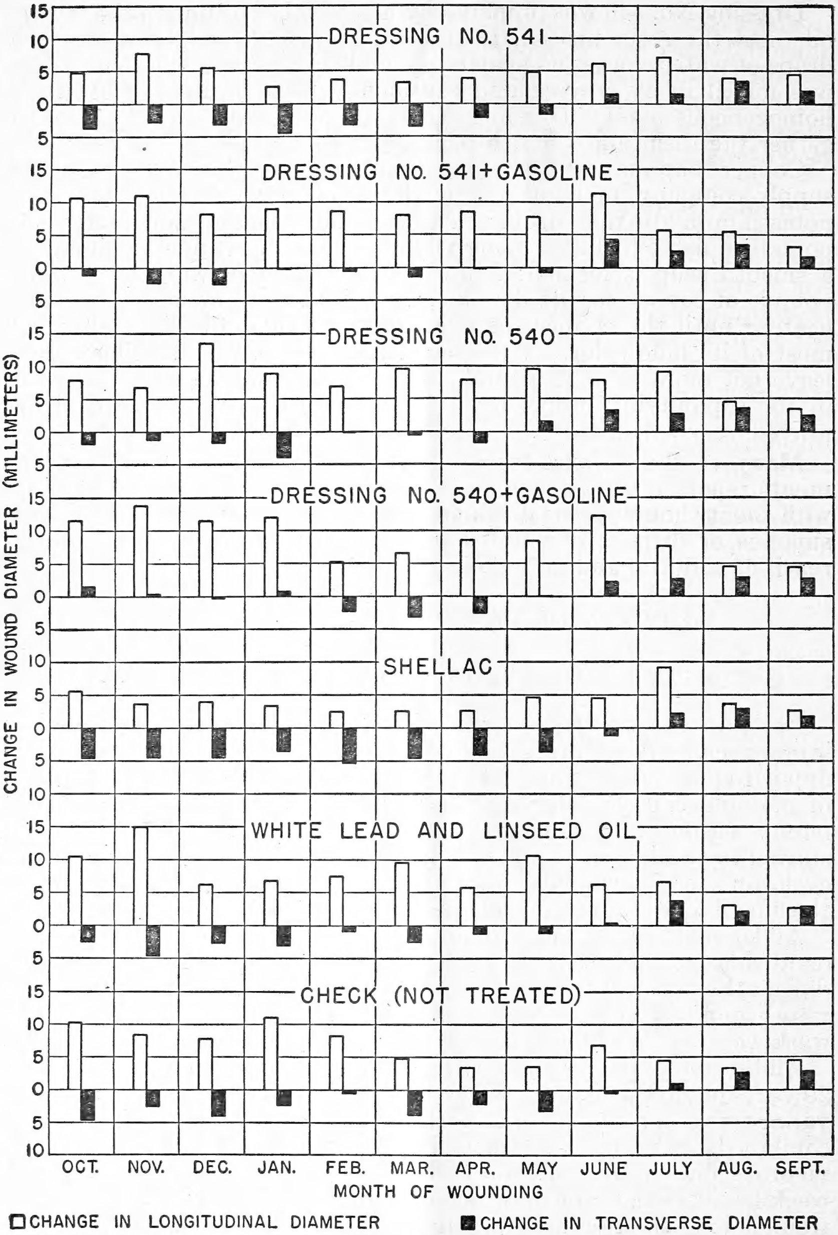

FIGURE 1.—Average changes by the end of the first season in longitudinal and transverse diameters of 25-millimeter wounds made in apple tree limbs in different months and immediately treated with various compounds. The 0 lines represent the original wound size (25 millimeters). Figures above 0 indicate wound extension by dying of tissue, and those below 0 indicate decrease in wound size by healing. Each average includes at least five wounds.

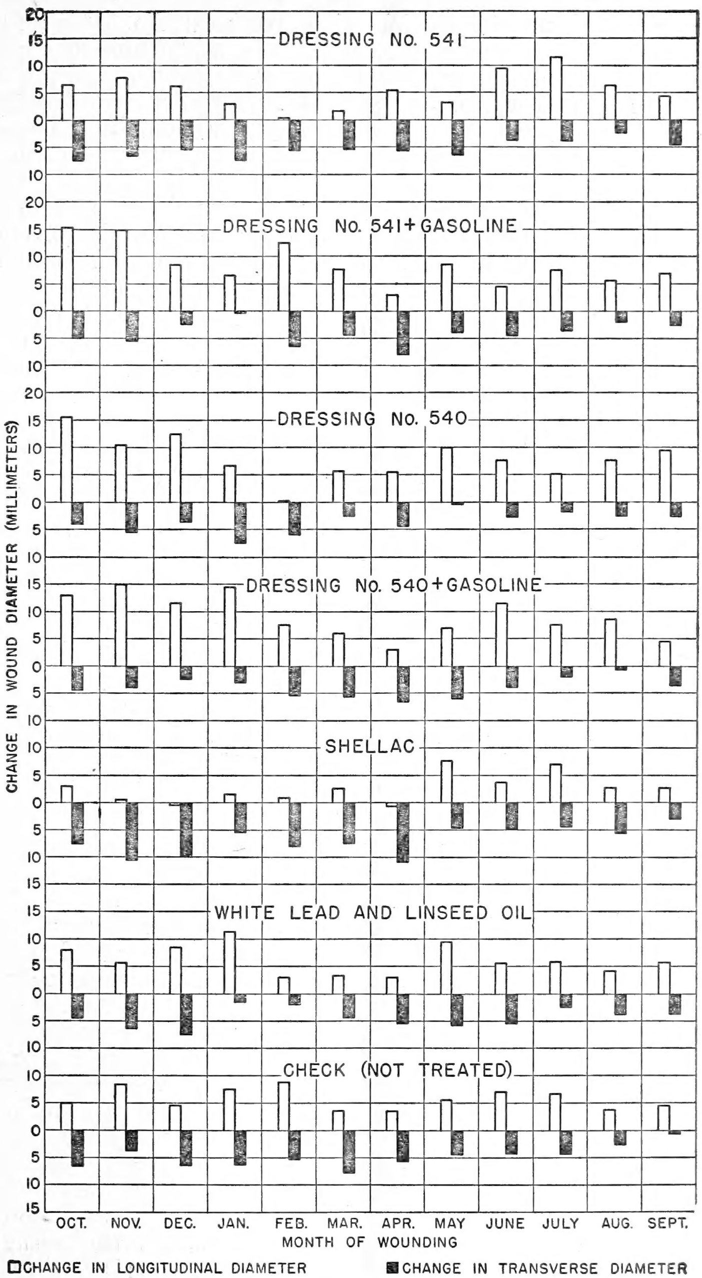

FIGURE 2.—Average changes by the end of the second season in longitudinal and transverse diameters of the same series of wounds shown in figure 1. The 0 lines represent the original wound size (25 millimeters). Figures above 0 indicate wound extension by dying of tissue, and those below 0 indicate decrease in wound size by healing. Each average includes at least five wounds.

experiments were run with the following dressings: No. 541 with 1 percent red oxide of copper; No. 541 with 1 percent black oxide of copper; a heavy proprietary wax resembling grafting wax; a wax emulsion with water; and also No. 540 and No. 541 with several different thinners. After the first year, experiments with only the first six preparations listed were continued, as these seemed to be the most satisfactory.

The detailed experiments reported were run from 1936 to 1938, inclusive, at Arlington Experiment Farm, Arlington, Va. At about the middle of each month for 2 years, circular side wounds about 25 millimeters in diameter were made with a 1-inch bit on the internodes of limbs. One or more wounds on at least five trees were immediately painted with each of the six dressings listed. In November of each year, after the leaves had been killed by frost, the transverse and longitudinal diameters of the wounds were measured. The wounds made from October 1936 to September 1937 were measured in October or November 1937 and in October or November 1938 and those made from October 1937 to September 1938 in October or November 1938 and in October or November 1939; hence, the October wounds were approximately 13 months old and the September wounds approximately 2 months old at the time of the measurements summarized in figure 1. Measurements summarized in figure 2 were made 1 year later when the same wounds ranged from approximately 25 to 14 months in age. They represent summation of healing and of dying of tissues around the wounds during the part of the first season after the time of wounding and through the entire second growing season.

Because certain limbs became devitalized or, in a few cases, labels were lost, it was not always possible to include in the second year's data all the wounds that were in the first. Some of the irregularities in the graphs for the second year may be thus explained.

Relation of Time of Wounding and Treatment to Healing

The results obtained when wounds and treatments were made at monthly intervals beginning in October of one year and measured the following October or November are shown graphically in figure 1; measurements made 1 year later are shown in figure 2. As may be seen by examining these figures, the longitudinal diameters of the wounds almost invariably increased, the extent of elongation probably serving as the best criterion for evaluating the various treatments. The data in figure 1 show considerable variability, but, in general, there was a tendency for greater elongation to occur in wounds made in winter than in spring.

The data of figures 1 and 2 regrouped so that those for November, December, and January are averaged as one unit and those for February, March, and April as another unit are graphed in figure 3. Such a grouping facilitates the comparison between winter and spring treatments. Although this particular grouping of months does not correspond to the calendar winter and spring seasons, it seems to conform more closely to the plant's response to season. Figure 3, *A*, representing the results at the end of the first year, shows that the longitudinal diameter is greater for the winter than the spring wounding and treating in every case. The same general tendency prevailed at the end of the second year (fig. 3, *B*) where all the treatments, except the shellac, showed less killing in the spring than in the winter. However, rapidity of healing in the transverse diameter was not so consistently correlated with the season of wounding.

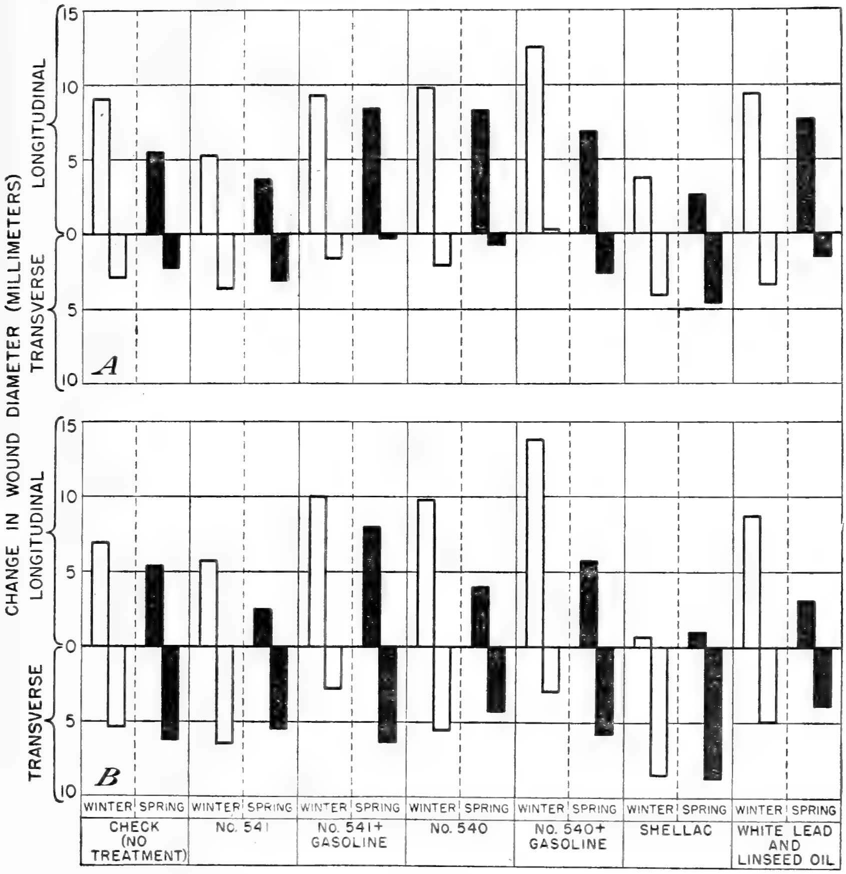

FIGURE 3.—Comparison of average changes in longitudinal and transverse diameters of wounds made in the winter months (November, December, and January) and in those made in the spring months (February, March, and April): *A*, At end of first season; and *B*, at end of second season. The 0 lines represent the original wound size (25 millimeters). Figures above 0 indicate wound extension by dying of tissue, and those below 0 indicate decrease in wound size by healing.

The data given in figure 1 for the condition of wounds at the end of the first growing season indicate that those wounds made before May showed more healing than killing in the transverse diameter. The wounds made in May and subsequently and treated with dressing No. 540 showed on the average more enlarging than healing. At the time of the June wounding and treating there was very slight closing of the wound by callus in the check and shellac treatments, whereas in all the other treatments the enlargement by killing was appreciable.

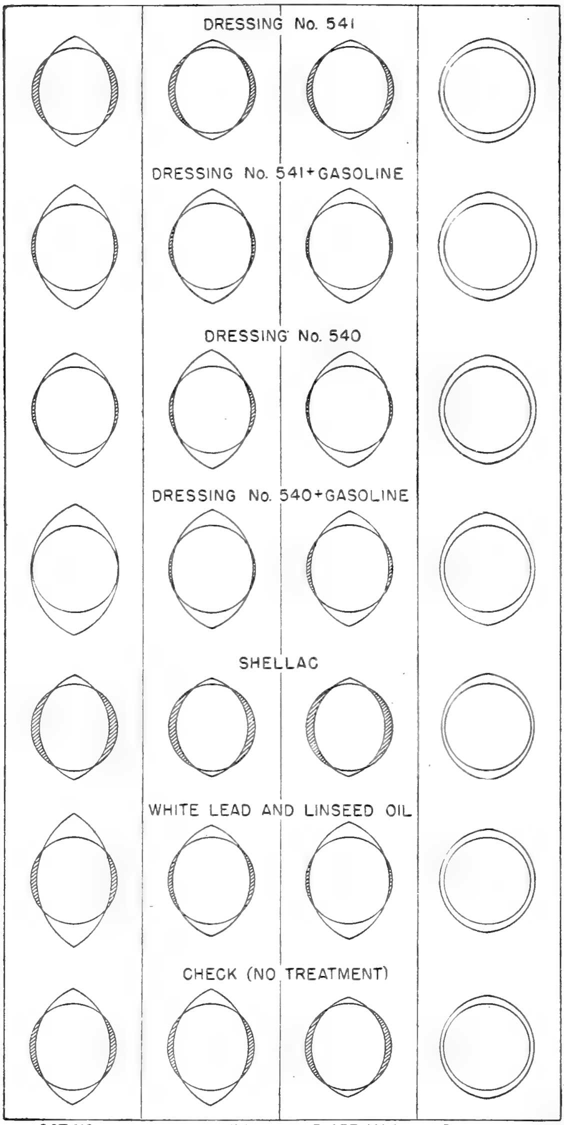

FIGURE 4.—Diagrams of average wounds in October or November of the first growing season after treatment determined by grouping into four seasonal groups the data by months in figure 1. In the diagrams, the circle represents the original wound (25 millimeters in diameter) and the ellipse, the shape of the wound when measured. The longitudinal diameter of the wound is represented by the long axis of the ellipse and the transverse diameter by the short axis. The shaded areas between circle and ellipse represent healing callus, and the unshaded parts of the ellipse outside the circle represent extension or enlargement of the original wound. Each diagram in the first column was based on the average of approximately 20 wounds, each in columns 2 and 3 on approximately 30 wounds, and each in column 4 on approximately 40 wounds.

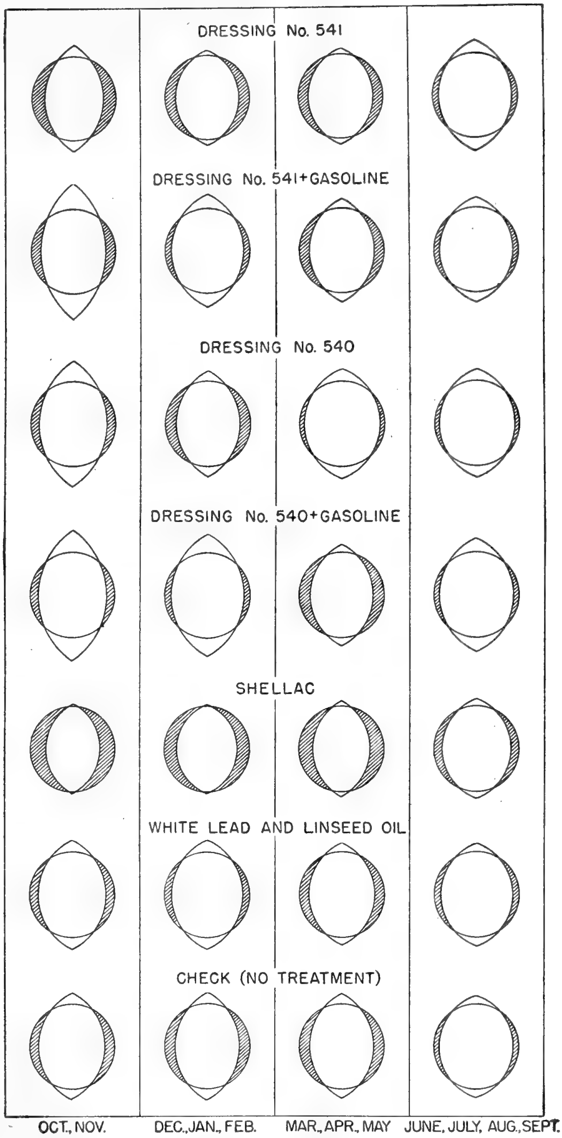

FIGURE 5.—Diagrams of average wounds in October or November of the second growing season after treatment determined by grouping into four seasonal groups the data by months in figure 2. In the diagram, the circle represents the original wound (25 millimeters in diameter) and the ellipse, the shape of the wound when measured. The longitudinal diameter of the wound is represented by the long axis of the ellipse and the transverse diameter by the short axis. The shaded areas between circle and ellipse represent healing callus, and the unshaded parts of the ellipse outside the circle represent extension or enlargement of the original wound. Each diagram in the first column was based on the average of approximately 20 wounds, each in the second and third columns on approximately 30 wounds, and each in the fourth column on approximately 40 wounds.

By July and later, wounds in all the treated plots showed no callus formation and consequently they enlarged because of dying and drying.

Observation of pruning wounds where a branch is removed, in contrast with internodal or side wounds, indicates that the longitudinal extension of pruning wounds when the tree is weakened is likely to be greater than that of side wounds. The difference between spring and winter treatments, therefore, would probably have been greater if the data had been taken for pruning wounds instead of for side wounds. When pruning or wounding is done just prior to excessive cold, enlargement of the wound because of winter injury may result. The work of Crenshaw and Cooley (*6*) showed that when subjected to experimental chilling fresh wounds enlarged considerably as the result of injury, whereas callused wounds and unwounded limbs showed no evidences of injury. Winter pruning or wounding, therefore, involves a hazard of winter injury about the wound, which does not exist in spring pruning or wounding. The winters were mild during the experimental wounding reported in this circular; so enlarging of wounds by cold injury was probably not so pronounced as it would have been in a year having extremely low temperatures.

The data reported by months in figures 1 and 2, respectively, were combined into four seasonal groups, which are presented diagrammatically in figures 4 and 5 to facilitate comparison of the shapes of wounds made at different seasons of the year.

Reaction of Wounds to Different Treatments

The wounds with different treatments showed some fluctuations in injury and healing. Such variation probably would have been much less pronounced if more wounds had been used and if the trees had been young and vigorous. The graphs show, however, that some dressings caused less injury and gave better callus growth than others. In order to facilitate comparison of one dressing with another, averages of the enlarging or dying and of the closing or healing measured at the ends of the first and the second season are reported in figure 6, *A* and *B*. Such averages partially obscure certain aspects of the data that the monthly records bring out, but they facilitate ready comparisons of the relative effects of the different dressings.

UNTREATED WOUNDS

At the end of the first season, the average longitudinal extension of the check wounds was less than that of those treated with No. 541 plus gasoline, No. 540, No. 540 plus gasoline, or white lead and linseed oil, but it was more than that of those treated with No. 541 or shellac. In average transverse diameter, which is an index of the amount of callus formed, only wounds treated with shellac had healed better than the untreated wounds (check). At the end of the second season the average data for wound size showed the same general trend as at the end of the first season. Some of the treatments showed still more striking differences when the averages for the spring months, as shown in figure 3, *A* and *B*, rather than those for the 12 months, were

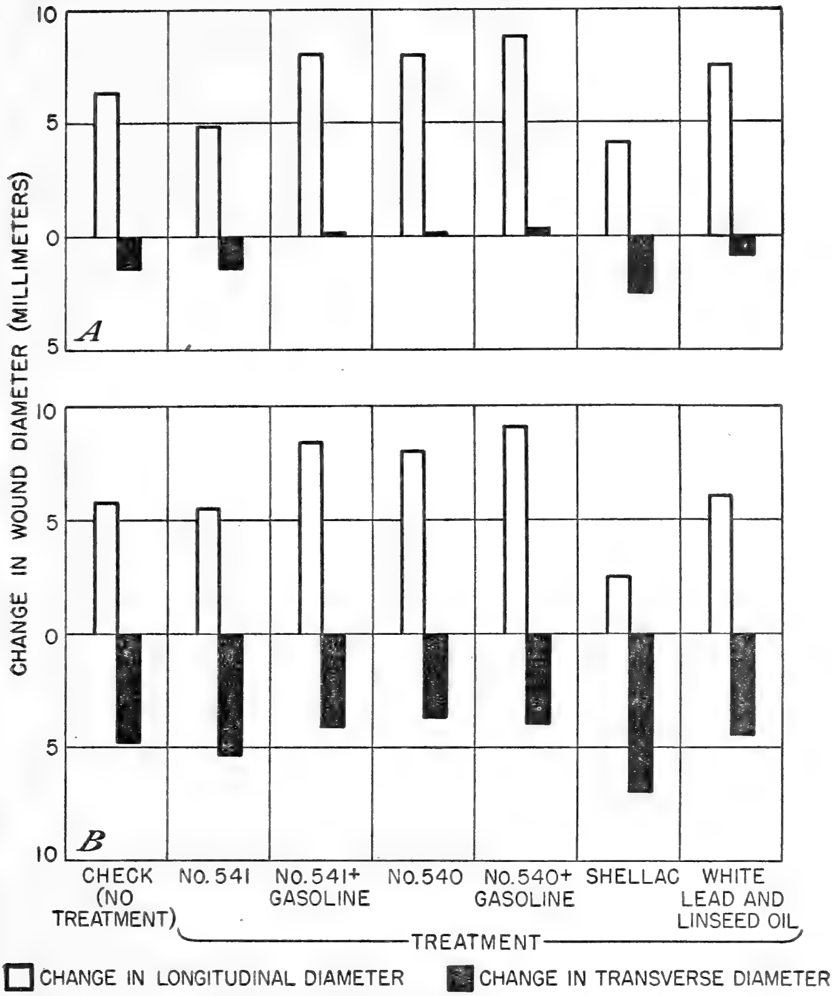

Figure 6.—Averages for the treatments shown by months in figures 1 and 2: *A*, At end of first season; *B*, at end of second season. The 0 lines represent the original wound size (25 millimeters). Figures above 0 indicate wound extension by dying of tissue and figures below 0 indicate decrease in wound size by healing.

compared. As the spring applications were made at the time when pruning wounds are usually made and treated, a comparison of the relative injury and healing of those wounds may be as important as or more important than that of wounds made at any other time. The relative merits of the different dressings should be studied by comparing the monthly data with the averages for the spring months and for all months. The effect of the spring application, however, will not be discussed separately for each treatment.

WOUNDS TREATED WITH DRESSING NO. 541

Dressing No. 541, which contained fish oil and rosin, was not expected to be harmful to fresh wounds. In the longitudinal diameter the average extension was less than with no treatment (check), and when the spring average is considered the difference is still greater; that is, dressing No. 541 seemed to prevent drying and dying in the spring, but at some other periods, as in summer, it caused some harm and more extension than no treatment. It was better than the white lead and linseed oil but poorer than shellac. Where a dressing having good covering properties to prevent cracking and water entering the wound is desired, this dressing, which gave better results than any other tried, is suggested.

WOUNDS TREATED WITH DRESSING NO. 540

Dressing No. 540, which contained copper soap, presumably would have mild disinfecting properties, but owing to the insoluble nature of the copper compound it was not expected to have harmful effects. However, the average killing or the extension of the longitudinal diameter was greater with this dressing than with No. 541, shellac, or white lead and linseed oil. Also the average healing was less with this treatment than with No. 541, shellac, or white lead and linseed oil at the end of the first growing season. Even though the dressing had good covering properties and protected the wounds from drying, there was still more killing than where no protection was given, as in the untreated wounds.

WOUNDS TREATED WITH SHELLAC

The shellac dressing did not provide the thick or waxy covering usually considered desirable to prevent drying and other adverse weathering effects, but better callus developed with this than with any other dressing. The wounds with no protection from weathering and those with the No. 541 treatment, which made a continuous waxy coating and presumably should be noninjurious, both showed more enlargement in the longitudinal diameter and less callus formation in the transverse diameter than where shellac was used. At the end of the second season the contrast between the shellac and no treatment (check) and other treatments was still pronounced. This was especially noticeable for the spring and winter treatments.

WOUNDS TREATED WITH WHITE LEAD AND LINSEED OIL

The dressing of white lead and linseed oil was better than dressing No. 540, but not so good as dressing No. 541 or shellac. White lead and linseed oil probably afforded greater protection from drying than shellac, but this beneficial effect was possibly offset by harmful effects, for the result in general was less healing than where shellac was used or even where nothing was applied.

WOUNDS TREATED WITH DRESSINGS NO. 540 AND NO. 541 PLUS GASOLINE OR OTHER SOLVENTS

Since it is sometimes difficult to provide warming facilities to melt a thick wax dressing, such as No. 540 and No. 541, it is desirable to know the effect of a solvent. When gasoline [5] was used as a solvent, enough was added to make the dressings of the consistency of a thick paint (see p. 5). At the end of the first season both No. 540 and No. 541 thinned with a solvent showed in general more extension or dying and also less callus growth than the same dressings without solvents. Other solvents used on parallel plots with gasoline were acetone, Varsol, and Bayol. All the dressings in which these solvents were used were more injurious than those containing gasoline.

WOUNDS TREATED WITH WAX EMULSION AND PARAFFIN

A wax emulsion was also used at most of the treatment dates. Because callus formation was not so good and was more irregular than where dressing No. 541 or shellac was used, results with this dressing are not reported in detail. Paraffin was tried as a wound covering at Hood River, Oreg. Wounds so treated made rapid callus growth, but the callus seemed thin and abnormal and was susceptible to winter injury. The action of paraffin on callus formation may be due to modifying aeration and respiration or to the presence of some growth-promoting substance. Experiments by Shear (*12*), which involved treating wounds with growth-promoting substances, indicated that callus formation may be accelerated by such substances.

WOOLLY APPLE APHID DETERRENTS AND APHICIDES IN RELATION TO PERENNIAL CANKER

In the early stages of these experiments the idea prevailed that infection by the perennial canker fungus occurred in fresh pruning wounds or cut-out cankers and, therefore, that a wound dressing containing a disinfectant should be effective in preventing canker infection. Subsequent work (*4*) demonstrated that infection with the perennial canker fungus takes place in new pruning wounds only under very restricted conditions and that by far the most important canker development in nature takes place in callused wounds that have been weakened or injured by cold. In the Hood River Valley and other localities in the Northwest, calluses on which woolly apple aphids have been feeding are much more susceptible to winter injury by low temperatures than calluses not infested with aphids.

When this work was being carried on at Hood River, Oreg., the woolly apple aphid infestation on the above-ground parts of apple trees was very serious. The feeding of these aphids on wound callus predisposed the callus to winter injury, which in turn made conditions favorable for infection by the perennial canker fungus. At that time, it seemed important to obtain information concerning the incorporation of an aphicide or an aphid deterrent in a wound dressing. For this purpose the following substances were tried: Creosote,

[5] Commercial gasoline not containing tetraethyl lead.

crude petroleum, nitrobenzene, oil of citronella, oil of sage, oil of eucalyptus, camphor gum, dipentene, isovaleric acid, amyl butyrate, pine tar, borneol, butyric acid, calcium cyanide, Paradow, anthracene, eugenol, Black Leaf 40, methyl sulfide, Evergreen (alcohol solution of the active principle of pyrethrum), naphthalene, castor oil, fish oil, transmission oil, medium paraffin oil, crankcase drainage, Crisco, rapeseed oil, tallow, butyric ether, oil of peppermint, oil of lemon, and amyl valerianate.

These substances, if compatible, were incorporated in a wax paint and applied, or, if incompatible with wax, were applied in a water paste of kaolin. Aphicidal and aphid-deterring properties were determined by covering part of a wound callus, usually where the aphids were already feeding, and recording later whether or not aphids were feeding on the untreated bark in close contact with the paint. None of the substances used, even those having the foulest odor, was either attractive or repellent to the woolly apple aphid. A film of oil seemed to be very objectionable to the aphids, but a light oil was soon volatilized and a heavier oil caused disturbance to the tissue, thus making its use questionable.

In the course of the experiments, attempts to increase the efficacy of waxlike dressings against the woolly apple aphid included repeated trials with nicotine through several years. The nicotine improved aphid control, as was also reported by Childs (*3*), but it was necessary to add lethal concentrations (10 to 25 percent) of Black Leaf 40, which greatly increased the cost. Dressing No. 541, by its protective covering alone, usually controlled the aphid satisfactorily without nicotine, if wounds were not painted until midsummer when callus formation was about over and before the usual heavy aphid attack in early fall had begun.

CONCLUSIONS AND PRACTICAL CONSIDERATIONS

The work reported in this circular emphasizes the importance of the time of the year in which pruning wounds are made. The later in the growing season pruning is done, the less time there is for callus formation that growing season, and completely uncallused wounds are subjected to enlarging by drying and dying till callus formation begins the next spring. As only side wounds were made in the summer wounding reported in this circular, the shock effect resulting from removing limbs when in leaf was probably not operative.

If wounds are made in the fall and early winter, the unhealed wounds are subjected to cold injury and other conditions that cause dying and extension. In regions where severe cold sometimes occurs, winter pruning may cause extensive enlargement of the wounds or even general winter injury to the whole tree. Even in the comparatively mild winters occurring when this work was done, there was more longitudinal enlargement of the wounds made in the winter than of those made in the spring. The same principle is illustrated by the fact that the dressings that were slightly injurious produced more injury in the winter treatments than in the spring treatments. Also, the increased longitudinal enlargement of wounds on a weak limb was much greater than on a more vigorous one.

Shellac gave less killing and more callus formation than any of the other dressings tried. Where a heavier covering than shellac is desired, dressing No. 541, which is composed of rosin and fish oil and gave good results, is suggested. The waxlike dressings gave better healing when applied warm than when thinned with the solvent, gasoline. Injury from the thinner was less in the spring treatments than in those of the other seasons. The injury from the thinner was not great enough to discourage its use for spring treatments, but it is inadvisable to use it for winter treatments.

If protection from woolly apple aphid about pruning wound calluses is desired, dressing No. 541, which gave better results than any other dressing, may be used. It should be applied as late as possible before the wound callus is infested. It usually afforded protection from woolly apple aphid throughout the summer.

In case shellac or rosin and fish oil cannot be obtained under existing priorities the orchardist should be careful what treatment he substitutes. The work reported emphasizes the injurious effect on wounds on apple trees of a wound dressing that is only slightly toxic. Before applying a disinfecting wound dressing, which will probably enlarge the wound, one should have information as to whether or not the disinfectant will retain its activity long enough to be useful and also whether the hazard of possible heart rot injury would be greater than the known hazard of wound-dressing injury.

SUMMARY

The most promising of a large number of wound dressings were tested on the limbs of mature apple trees at Hood River, Oreg., and at Arlington Experiment Farm, Arlington, Va. Internodal or side wounds 25 millimeters in diameter made at monthly intervals for 2 years were treated with two waxlike dressings in comparison with white lead and linseed oil, shellac, and no treatment. One waxlike dressing (No. 541) contained eight parts by weight of rosin and three parts of sardine oil; the other (No. 540) was similar except that it contained copper soap in addition.

More rapid healing took place in the transverse diameter; in the longitudinal diameter the wounds enlarged by dying even where the best dressings were used. Even at the end of the second growing season the longitudinal diameters of the wounds were larger than at the beginning.

Wounds made in June or later produced little or no callus, in which cases enlargement due to dying took place in the transverse as well as in the longitudinal diameter. The longitudinal extension of wounds made in winter was in general greater than that of those made in the spring. The slightly injurious dressings caused less killing when applied in the spring than at any other time of the year.

Shellac gave more callus formation and less dying or longitudinal extension of the wound than any other dressing used. Dressing No. 541 gave better healing in general than white lead and linseed oil or dressing No. 540. The untreated wounds gave better healing in general than those treated with white lead and linseed oil, but poorer than those treated with shellac.

When protection from the woolly apple aphid on wound callus is desired, dressing No. 541 is suggested, as the best results were obtained with it.

In case shellac or rosin and fish oil are not available under existing priorities an orchardist should obtain information about the proved merit of any dressing that he proposes to substitute because, as the experiments reported herein show, a wound dressing only slightly toxic may have an injurious effect on apple tree wounds. The hazard of such dressing might be greater than that from possible heart rot injury.

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