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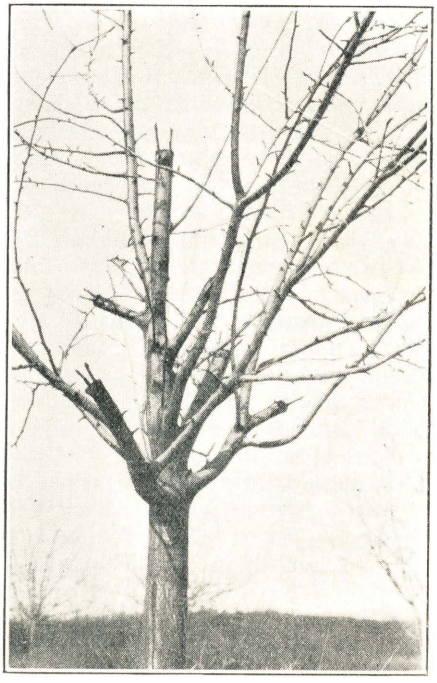
BY H. A. CARDINELL AND F. C. BRADFORD



AGRICULTURAL EXPERIMENT STATION
MICHIGAN STATE COLLEGE
Of Agriculture and Applied Science

SECTION OF HORTICULTURE

East Lansing, Michigan

GRAFTING IN THE APPLE ORCHARD

H. A. CARDINELL AND F. C. BRADFORD

Even though the fruit grower buys his trees ready-made, budded or grafted in the nursery, he is likely sooner or later to encounter contingencies which render grafting desirable or even necessary. Nurserymen occasionally make mistakes and some of the ready-made trees may prove, on coming into bearing, to be of varieties other than the labels indicated. Growers, too, sometimes make mistakes and order varieties which prove undesirable. Examples of these cases will occur to every experienced fruit grower. Market conditions may change, leaving the grower with an orchard of trees bearing fruit which cannot be sold advantageously, as has happened in parts of Michigan on a large scale with the Duchess apple. In other cases, market demands may render desirable the growing of certain varieties such as Grimes, King, or Red Canada (Steele's Red), which do best when grown on a hardier or a sturdier trunk. In still other cases, though the variety remains unchanged, repair work essential to keeping the tree in good condition may involve certain types of grafting.

The present paper is not intended as an exhaustive treatise on the curiosities of grafting. The experimentally inclined person will soon discover that there is an almost endless variety in the possible ways of making grafts grow and that almost every rule given may be violated and still some grafts will take. Many generations of experience, however, have shown clearly that certain methods are most likely to be successful under ordinary conditions. These are presented here.

DEFINITION OF TERMS

Stock, signifies the root, tree, or portion of a tree into which the graft is set. Ordinarily it furnishes the root system of the completed tree and it may furnish a portion of the top. In most cases it is grown from seed.

Cion denotes the piece of twig grafted into the stock. From it grows a branch or a whole tree top which bears fruit according to its kind.

Cambium layer refers to a certain layer of living cells surrounding all woody portions of the tree. During the growing season these cells are constantly dividing, forming new cells; those produced on the inside, form wood and those on the outside form the inner bark. Consequently the cambium layer is the source of all growth in the thickness of the woody stem and of most callus formation, particularly in older wood. It is the most distinctly live tissue in the stem and its preservation is essential to further growth. Recent investigations in Massachusetts have shown this layer in young apple wood to be from six to ten cells only in thickness.

Therefore the exact limits of this zone of growth can hardly be discerned with the unaided eye. Its location, however, can be recognized from the statement that peeling the bark from the tree while the bark is loose ("slipping") splits the cambium layer, part adhering to the bark and part to the wood. The paste-like substance that can be scraped at this time from the wood surface exposed by lifting the bark, is composed in part of cambium-like cells.

Top-working means the grafting over of a tree on the trunk or in the branches, as distinguished from grafting or budding near the ground or in the roots.

SELECTION AND CARE OF CION WOOD

Cion wood should be selected from the most recent growth. For example, cions set in the spring of 1934 should be cut from wood grown in 1933. This can be distinguished readily from older wood by starting at the tip and proceeding backward to the first ring of scars encircling the twig (Fig. 1). This ring marks the position of the bud scales where growth for the year began. Behind it the bark differs markedly and in vigorous trees the older wood has spurs instead of the simple buds that characterize the young wood. For the increase of cion wood of a new or rare variety, somewhat older wood may be used. Cions cut from three-year wood have grown in the college orchard, but the percentage of "take" is low, and older wood should not be used for commercial top-working. An exception to this rule, applicable under special conditions in bridge grafting, is noted later.

Twigs which have made a growth of from one to two feet in the last season ordinarily furnish the best cion wood. Cions the thickness of a common lead pencil are preferable. Very careful investigation in Illinois has shown that the position of the twig on the tree is of no importance. Water sprouts make good cion wood—provided they do not originate below the graft—if the buds are well developed and the wood well matured, and the available evidence indicates that grafts from water sprouts will make just as fruitful trees as those from any other position on the tree. Furthermore, as they remain dormant longer, when cions are cut late the water sprouts make the best cion wood. The only objection to them lies in the fact that they are likely to be immature and if the cions are cut in the spring this wood may have been damaged somewhat by cold weather. Very vigorous growths on the ends of branches are open to the same objection. Twigs showing discoloration in the pith or wood should be discarded or cut back to sound wood.

Immature tips should be discarded, not only because of their liability to winter injury, but because they are likely to have poorly developed buds, and to lack stored food materials for forming callus tissue and starting growth. The bases of very vigorous twigs also may be poorly suited to use as cions. Other things equal, if a long twig be divided in imagination into four sections of equal length, the best cion wood will be found in the two inner quarters. Twigs showing many aphis eggs should be cleaned or discarded, preferably the latter.

Cions may be cut at any time while they are dormant. If taken in the fall they will be safe from winter injury; they can be buried horizontally in a well drained spot; depth sufficient to protect them against drying out is ample. Cions cut in midwinter have been kept successfully by burial in a snowdrift on the north side of a building. Careful wrapping of the bundles in cloth or heavy paper to keep them from direct contact with earth, will save the edges of the knives at grafting time and perhaps save the spoiling of many cions from dull knives. If soil does adhere, the twigs should be washed before they are cut into cions.

Fig. 1. Cion wood. At the right the tip is undesirable because of immaturity; the center twig is good except very close to the base. At the left is a twig of a type which often deceives the unobserving. The growth of the past season is confined to a very small portion near the tip; the rest is too old to make good cion wood. Note the way the buds stand out on this twig; these buds are not laterals, like those on the other twigs, but are on very small spurs.

Cions should be dormant when they are set. This is important and even almost essential. Dormant cions will grow if set into stocks which have advanced to the blossoming stage, or sometimes even farther, but the percentage of "take" falls off very rapidly with the advancement of the buds on the cion. Since, for reasons to be explained later, the failure of any considerable portion of cions to "take" may seriously impair the ultimate success of those which do, grafting with cions whose buds are opening should not be attempted, unless under exceptional conditions. As a temporary means of preserving and increasing a supply of rare cion wood which would be lost otherwise, it is justifiable and may even be measureably successful, particularly if the grafts are shaded for a time with paper sacks or coated with paraffin, but if dormant cions are lacking commercial top-working should be postponed. Sometimes, after all wood suitable for cions in the orchard has started, it is still possible to obtain a limited supply from trees in a nursery storage shed.

SEASON FOR GRAFTING

Grafting for top-working in the apple orchard can be done to best advantage at about the time when the buds are beginning to swell. The cleft and tongue (whip) grafts, used in top-working, may be made while stock and cion are still dormant or they may be made with dormant cions on trees which have advanced to blossoming, though this last time is rather late for best results. The period just before the bark begins to slip offers some advantage in cleft grafting because at this time the bark and the wood split at the same point while when the bark begins to slip it sometimes splits a little to one side of the cleft in the wood and the proper placing of the cion becomes difficult.

Bridge grafting can be done much more easily and with a higher proportion of "takes" after the bark has begun to slip. Any of the methods used in adjusting the cion to the tree for bridge grafting involves the raising of more or less of the bark and to do this before the bark slips is extremely difficult.

THE CLEFT GRAFT

The cleft graft is made by inserting the cion into a split in a stub left upon sawing off a branch, or, sometimes in small trees, the main trunk.

Discrimination in selecting the points where the limbs are cut will be justified by the results. For reasons which will appear presently, grafting of limbs at points where they are over two inches in diameter should not be attempted and cleft grafts set in limbs of diameter less than an inch will require special attention. Selection of points where the wood is straight-grained and free from large knots or scars for six inches below the cut will ensure a straight and uniform cleft and thus help materially in fitting the cion. Furthermore, selection of these points should be made with the reconstructed tree in mind. Of this, too, more later.

The cut should be made square. This is not of particular importance so far as concerns the "take" of the cions, but it favors complete healing. Furthermore, it permits more latitude in the direction in which the cleft is made. Some operators smooth the cut with a knife; others, using a saw with fine teeth and little set, make no further attempt at smoothing. Smoothing the cut surface makes the locating of the cambium zone easier and helps beginners set cions more exactly. In most cases, however, there is little discernible difference in the results.

The cleft can be made most advantageously with a special tool for this

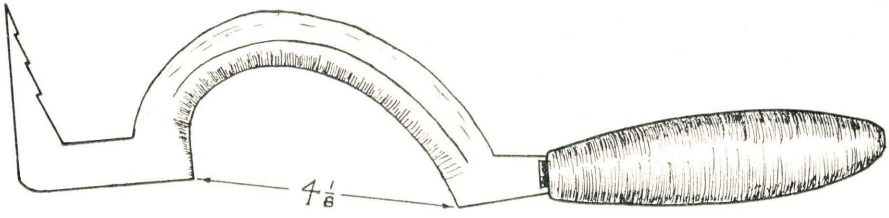


Fig. 2. A grafting tool for stocks of various sizes. The wedge should set out well from the cutting portion. Note the varying curvature of the cutting edge. Lower the handle for small stock; raise handle for large stock.

purpose. Its nature is indicated in Fig. 2 and Fig. 3; tools of this sort can be purchased from the larger seed and supply houses, or they can be made by a blacksmith. The purpose of the concave outline of the cutting edge is to ensure cutting of the bark, particularly in the upper part, before the wood is split, thus in some measure avoiding tearing of the bark. Besides this, it will aid in securing a uniform cut in wood of twisted grain. If one of these tools is to be made primarily for a single job, where there is considerable uniformity in the size of the stubs to be grafted, the radius of curvature, ("degree of convexity") of the cutting edge can be made to fit the size of the stubs. The smaller the stubs, the smaller should this radius be (the greater the "degree of convexity"), as shown in Fig. 3. The types commonly sold have a uniform curvature in the cutting edge and for this reason cannot be equally suited to stubs of all sizes. If the tool fits the large stub it splits the smaller with very little cutting; if it fits the small stub it crushes the edges of the larger before splitting begins. No edge has been devised within the bounds of practicability to fit all stubs equally well, but an approach to an edge of this kind can be made with a curve of more or less steadily increasing radius (Fig. 2). With the tool shown in this cut,

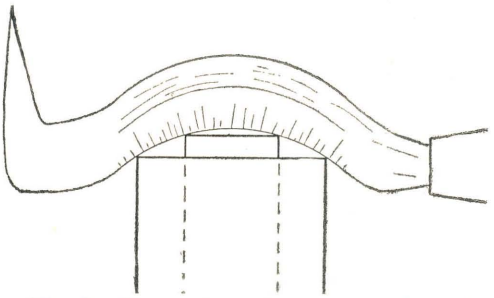


Fig. 3. Illustrating the reason for the varying curvature of the cutting edge shown in Fig 2. Uniform curvature does not fit stocks of various sizes.

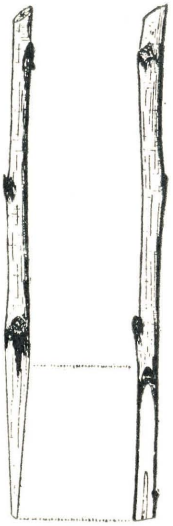


Fig. 4. Cions trimmed for cleft graft.

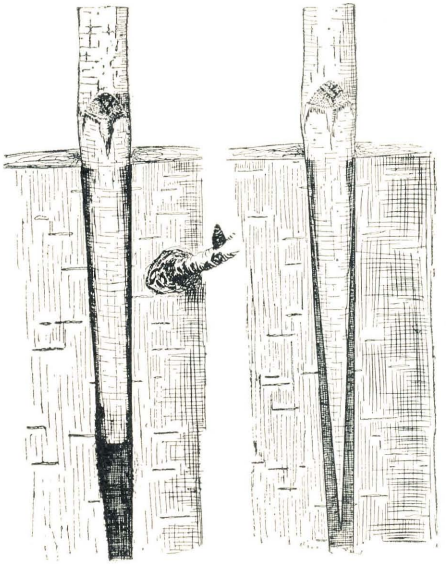


Fig. 5. Drawing the bevel out to a point (right hand figure) is likely to diminish the extent of the contact surfaces and to produce a "rocking" cion.

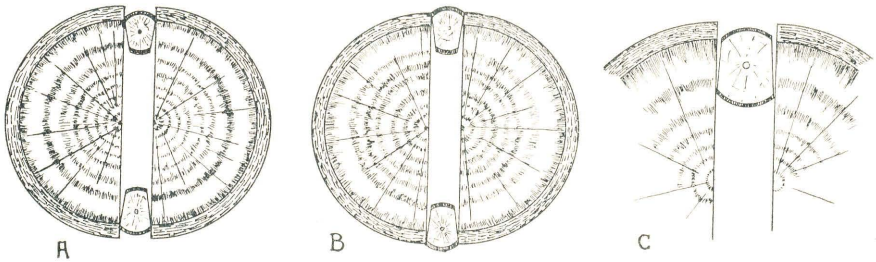


Fig. 6. Why some grafts fail. Lack of cambial contact between stock and cion can come about in more than one way. A shows grafts properly made and properly set; B shows failure of contact through setting the surfaces flush; C shows failure through undue thickness of inner part of cion.

holding the handle upward adjusts the edge to the larger stubs, holding the handle down adjusts it to the smaller and the intermediate sizes can be reached fairly well by holding the handle level.

Cions for top-working are generally cut to three buds. They are trimmed about one-fourth inch above the top bud, with the cut sloping somewhat down to the side opposite this bud. Terminal buds may be flower buds and should be discarded. The lower cut should be made one and one-half inches or more below the lowest of the three buds.

The bevel cuts shown in Fig. 4, should be so made as to ensure the greatest possible cambial contact. This increases the chance of union and also increases the rate of growth of the cion. It is not necessary, and in fact it is often distinctly undesirable, that the cion be trimmed to a pointed wedge. Fig. 5 shows that this sort of wedge often reduces the area of possible contact and, furthermore, since the contact surface is reduced the cion is held less securely and is likely to "rock" at a slight touch or to blow over later when it has grown enough to present considerable surface to the wind. Extremely long cuts, drawing the wedge out to a very thin point have no special advantage, except a possible greater cambial contact. Actually, however, in many cases this possibility fails of realization. Minor irregularities in cion or in stub make very long contacts difficult to establish. In addition, the thinness of the wedge ex-

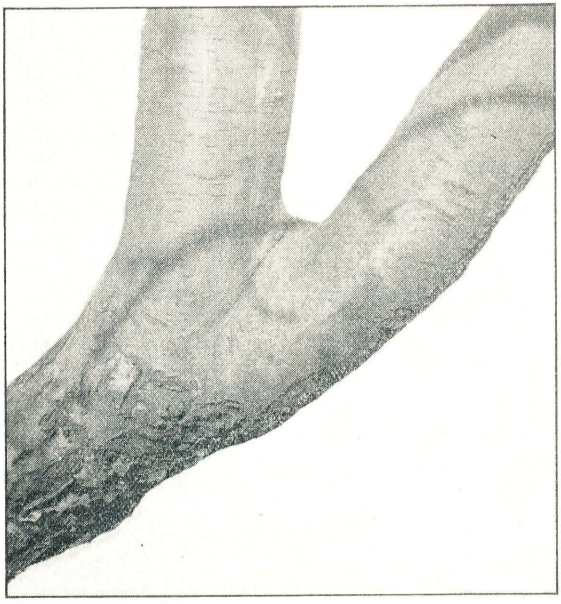


Fig. 7. An old graft. The basal bud has made a strong side branch, with a strong crotch. Contrast with Figure 13.

poses the pith on the bevel surfaces and cuts the woody cylinder surrounding it into two separate pieces which turn or crush under the compression of the stump when the grafting wedge is removed. This is particularly important in small cions. Whatever happens, however, the wedge must not be so thick as to prevent the top of the stub from clasping it. Contact all along the cut is desirable, but contact at the top of the cut and of the stub, is essential to a good union.

The upper edge of the bevel cuts should be at, or slightly below the level of the lowest of the three buds. Stored food reserves are more abundant here and callus formation, essential to the graft union, starts here first and is more abundant.

The "outside" of the cion should be thicker than the "inside". This ensures contact between the stock and the cion at the region of the cambium (Fig. 6). If this precaution is not taken, a slight accidental unevenness may prevent the closing of the stock sufficiently to bring the outer edge in contact with the cion.

The lowest bud should be on the outside. This ensures the placing of the zone of richest callus formation at the point where cambial contact can be secured with greatest certainty and where the union between stock and cion is of greatest importance to the subsequent healing of the stub. Furthermore, in many cases, from this bud develops a shoot which can be developed into an important part of the new framework (Fig. 7). If this bud faces in any other direction the new shoot must grow out across the stub and its subsequent expansion with increasing age will crowd it against the stub with ultimate danger to the graft. In addition, this young shoot stimulates wood formation below it and this should be on the outside of the cion where it increases the strength of the graft union rather than on the inside where it only makes callus, which tends to wedge the sides of the stock farther apart.

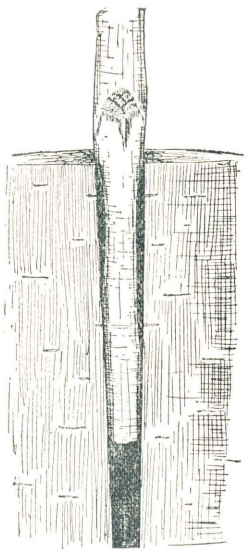


Fig. 8. Another cause of failure — irregular bevel, generally the result of poor edge on knife or failure to employ a draw cut. The hand should be held rigid and the arm muscles used in moving the knife.

The bevel cuts should be continuous and uniform. Otherwise cambial contact will be much reduced and the cion less securely anchored (Figs. 8 and 17). The surest means of securing a uniform cut is to use a knife with a rigid and very sharp thin blade. Experienced operators generally grasp the cion in the left hand, holding it horizontal, with the tip under the thumb and resting on the first two fingers and with the lowest bud uppermost. With the right hand holding the knife almost vertical but with the tip pointing a little to the right, the first cut is made, starting beside the lowest bud and proceeding to the end with one shearing cut. The cion is then rotated so that the basal bud moves 90 degrees to the right and down; the left hand remains in the same position and the cion is rolled between the thumb and forefinger. The right hand assumes a horizontal position, with the back of

the hand up, the knife blade pointed to the left and very slightly down, and the thumb below the cion. The second cut is made from this position. In each case the cut is made by drawing the knife toward the operator.

SETTING THE CIONS

The cleft stub is wedged apart far enough to admit the cions. In default of a better tool a screw driver may be used, inserting the blade into the fissure and then turning it. It is more convenient and satisfactory, however, to use a wedge attached to the tool used for the splitting. A smooth wedge will sometimes give trouble by slipping out. This can be prevented by a few ridges pointing backward on the wedge; these should be on one side only, else the wedge cannot be freed readily after the cions are set.

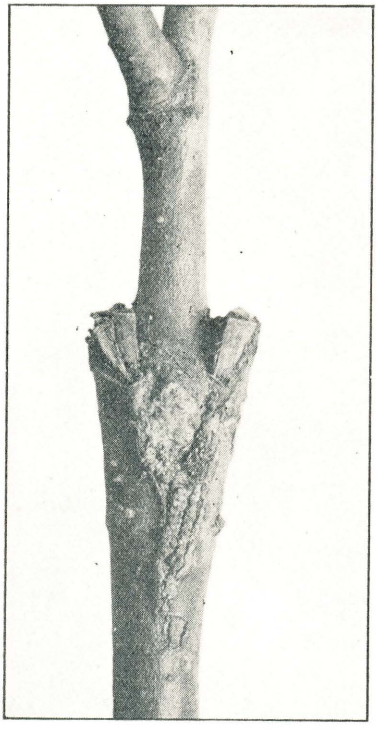


Fig. 9. Stock too small for easy use of the cleft graft. Union made and growth proceeding, but cion set too deep to permit ready healing of stock.

The cion should be inserted so that its cambium layer is practically continuous with that of the stock. In any case, contact at the top of the stub is essential to good union, and contact along the rest of the cion favors better growth. Microscopical examination of successful grafts has shown that absolute continuity is not essential to a "take", but contact so far as the unassisted eye can tell is desirable. Failure to secure this relative continuity in many cases results from setting the cion with its surface flush with that of the stock, disregarding the difference in thickness of the bark on the stock and that on the cion (See Fig. 6).

Sometimes the cions are tilted somewhat, supposedly to ensure cambial contact since the layers must cross at some point. Unless the bevels have been cut perfectly, this practice is dangerous since the crossing may occur at a point where there is no contact. Furthermore, tilting the cions almost inevitably leads to failure to secure contact at the top of the stub. This failure makes the stub, like any projecting stub left in pruning, very slow to heal over. As the cion grows, its woody tissues, instead of flowing readily over the stub, accumulate at its side in a large knorl composed of fibers changing direction very rapidly and in aggravated cases this has led after several years to breakage of the cion, not at the union, but along the line of greatest bending of the woody tissue. This condition is, perhaps, worse when the cion is of a variety making grosser growth than the stock, but the danger is so great that tilting of the cions cannot be recommended in any case.

The cion should be set so that the tops of the bevel cuts are level with the top of the stock in which it is set. Deeper setting would prevent the growth of callus from the stub and consequently delay, if it did not actually prevent, the healing of the union. Furthermore, the expansion of the cion will tend to spread the halves of the stub farther apart (Fig. 9). Setting the cion somewhat higher, so that some of the cut surface projects above the stub, is less injurious in its effects provided these exposed surfaces are covered with grafting wax. If the stock has been split too deep the cion should still be placed at the proper level and contact ensured by drawing the split portions of the stock together with a thick cord or a strip of cloth tied about the stock close to the top. Even if this does cause some girdling it should not be removed during the first season. The girdling will not be injurious and with the tie removed the growth on the cion would be likely to spread the stub.

Two cions should be set in each stub and both should be allowed to grow for a time. Generally, one of them must be removed sooner or later (see under "Subsequent Care") but for a time both are needed to ensure rapid healing of the stub. If a stub larger than two inches in diameter is to be grafted (though this is not recommended) two parallel clefts may be made, extending on either side of the center and two cions set in each cleft, making four for the stump.

All cut surfaces should be covered with grafting wax. For this purpose the brush wax, discussed later under "Grafting Wax" is recommended. Waxing is sometimes said to be for the purpose of keeping the moisture out; actually the purpose is keeping the moisture in. Some little care is necessary to avoid leaving minute air holes close to the cion, particularly in the part above the stub. Wax should extend down on two sides of the stub, closing in the clefts and for an inch or so beyond any visible cleft. Difficulty in covering the cleft in the top of the stub may be avoided by first filling it loosely with crumpled paper, though this is ordinarily unnecessary. Waxed cloths are not needed in cleft grafting the apple.

Waxing not only serves to keep moisture in but it may also prevent infection by wood-destroying fungi. This is doubly important in case either stock or cion has "black heart," a form of winter injury which makes it much more liable to fungous invasion. Cion wood in particular is sometimes slightly affected, not sufficiently to interfere with vigorous growth, but enough to predispose it to infection. Consequently, as a precautionary measure, cut ends should be waxed.

The most common causes of failure of cions to grow in the cleft graft, as in others, are (1) uneven edges on cion; (2) failure to secure proper cambial contact; (3) imperfect waxing; (4) lack of dormancy in the cions.

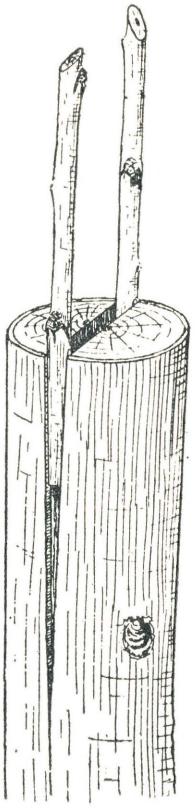


Fig. 10. Cleft graft complete except for waxing. Note correct position of lowest bud on the cion.

THE TONGUE OR WHIP GRAFT

The tongue or whip graft is particularly suited to cases in which the cion and the stock in which it is to be set are of approximately the same size. In these cases it is superior to the cleft graft because of the quicker healing secured. The more nearly the stock and cion approach equality in size the greater is the probability of success.

In this graft, both stock and cion are cut to match. A uniformly sloping cut, from one to one and one-half inches long (the larger the cion the longer the cut), is made in each. On both stock and cion a slit is made, beginning at a point one-third of the distance from the "toe" (sharp end) to the heel (Fig. 11). This slit may run exactly with the grain or it may cut across the grain slightly in the general direction of the heel.

Fig. 11. Tongue or "whip" graft. From left to right: (1 and 2) stock and coin ready for grafting; (3) cion in place. Note three contact surfaces; (4) placing of cion on larger stock.

If the cion is smaller than the stock, it must be set on one side to secure cambial contact at the tongues (Fig. 11). When this is properly done, cambial contact is secured on three surfaces.

If, when stock and cion are united, the toe of either projects much beyond the heel of the other, it should be cut off even. This can be done without disturbing the graft. The slow healing resulting from failure to correct this condition is shown in Fig. 12.

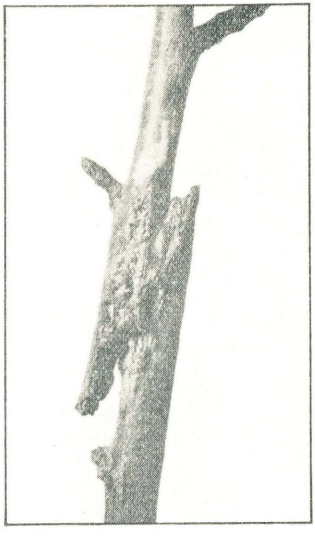


Fig. 12. Imperfect healing in tongue graft resulting from improper fitting of cion and stock.

Tying of tongue grafts, even when they are used in top-working, is not necessary. This was at one time a universal practice but many nurseries now employ this graft in top-working without tying and in the college orchard grafts well set were held perfectly by the wax alone. If ties are used they should be of soft cotton yarn and they should be cut as soon as the graft is growing well. This will be difficult, as the ties are covered with grafting wax, but failure to cut will cause girdling of the graft and is likely to check the growth of the cion and interfere with healing of the union. Grafting tape, recently placed on the market, has given very promising results; it is an effective tie and is much easier to remove.

The same grafting wax is used with the tongue as with the cleft graft. Waxing is just as essential in this as in the cleft graft and, if tying is omitted, it is needed also to hold the cion in place. As in the cleft graft, great pains should be taken to make the wax coating air tight, and every cut surface, including the tip of the cion, should be covered.

Beginners' most common faults in attempting this graft are: (1) failure to make the sloping cuts long enough; (2) uneven slopes arising from dull knife or failure to support the twig properly from the back when making the cut; (3) improper placing of the slit; (4) failure to press the tongues in deeply enough. All of these reduce the surfaces of actual close contact, often sufficiently to cause failure or very slow healing with consequent danger of infection by wood-rotting fungi.

SUBSEQUENT CARE OF GRAFTS

Care of the grafts even after they are well established is important and should not cease until the union is completely healed over. Two purposes should be kept in mind in this work: (1) the prevention of invasion by wood-rotting fungi (Fig. 15), and (2) the formation of the framework of the new top. In addition, protection against climbing cut worms, aphis and fireblight may be necessary, particularly in the first year. Within a short time after the grafts are set they should be examined for defective waxing and rewaxing should be done each fall and spring until healing is accomplished. Complete rewaxing is not necessary; ordinarily callus formation will seal the sides of the cleft in the first sum-

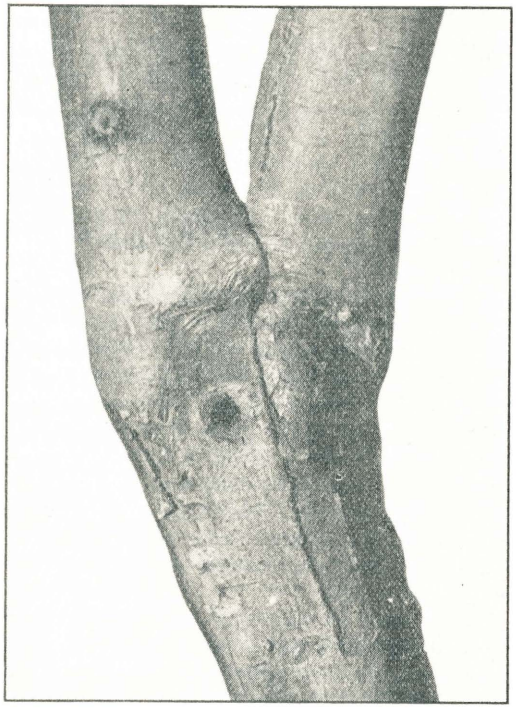


Fig. 13. An old graft with cions crowding; a source of weakness. One cion should have been removed long ago.

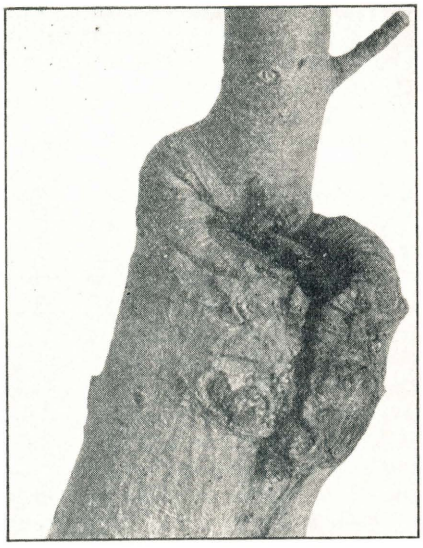


Fig. 14. Slow healing and decay from premature removal or failure of second cion.

Fig. 15. An inside story with the same moral as Fig. 14. This limb was grafted twice. The lower union is sound; decay started in the upper before the retarded healing could seal the union.

mer and they will require no further attention. At the top of the cleft, however, several renewals may be needed. If the wax is at all hard and lacking in pliability the expansion of the cions through growth is likely to cause it to buckle and loosen. In such cases all loose pieces should be removed and fresh wax applied.

About July 1, in the first season of growth, pinching back of the vigorous shoots from the cions may be desirable. This is done to induce low branching and to keep the framework of the new fruiting top as close to the ground as possible. Only the soft green wood at the very tip should be removed; this can be done with the thumb and forefinger. Heavier cutting back would have a somewhat stunting effect and should not be practiced at this time.

Both cions on each stub should be allowed to grow for a season, at least. Eventually one is to be removed, since if both grow to full size a weak crotch is formed, the new wood on the inside of each cion pushing against the other cion, and splitting out is likely, just as in an acute-angled crotch (Fig. 13). For a time, however, both are needed to keep the stump alive throughout. On a two-inch stump a cion will induce callus formation on the corresponding half of the circumference, but because of the slowness in the lateral movement

of food materials coming from the growing cion, it is unable to supply the opposite side sufficiently to maintain life and this part of the stump dies. To make a good union all of this dead area must be sealed in by growth from the edges —always a slow process—and before this can take place decay is almost certain to begin (Fig. 14). If, however, live cions on both sides are feeding the stump, it remains alive in every portion. If one cion fails, any nearby water sprout should be saved for a time and treated as the "subordinate cion" (see next paragraph).

Growth proceeding from one of the two cions on each stump should be kept distinctly smaller than that from the other. This is to prepare for the ultimate removal of the smaller. If both make equal growth the removal of one will leave a relatively large wound which may be slow in healing (Fig. 16). A cion kept small for several years will suffice to prevent the death of any part of the stump and when it is removed will leave a small wound. In the meantime the other cion will have attained considerable size and will be able to supply enough food materials to heal the small wound in a short time.

The subordination of one cion is effected by pruning it more heavily than its companion. This differentiation may begin at the time of pinching in the summer following the setting of the grafts and should receive attention each succeeding spring while the cion is retained.

The removal of the subordinate cion should not occur until the bases of the two cions meet. This time will vary with the vigor of cion growth and with the size of the stump. With vigorous growth on the smaller stumps removal can occur in many cases in one year; in others the period may be three or four years. When the cut is made it should be close enough to leave no projecting stub.

Water sprouts should not be removed indiscriminately. Their utilization is discussed later, under "Top-working."

THE BRIDGE GRAFT

A bridge graft (Fig. 19), as the name implies, is used to bridge over an area where the cambium is dead. In practice it is used most frequently in Michigan to repair damage from gnawing by mice or rabbits or occasionally from bark peeling by sheep. More use should be made of this type of graft in repairing damage from fire blight cankers on the trunk and from winter killing.

At this point, a word of caution may be introduced. Bridge grafting is no small consumer of time and labor and in some cases careful study will show a means of avoiding this work with satisfactory results. Sometimes, mice apparently ring a tree, gnawing the bark completely around the trunk, but actually fail to touch the cambium. If attention is given before drying out has occurred simple mounding with earth or wrapping with waxed cloth will be sufficient to permit regeneration of the bark.

The proper treatment of a wound made by a tillage implement tearing off a considerable piece of bark when it is slipping freely will in many cases, save the necessity of bridge grafting later. Under such circumstances most men rub some earth over the wound, perhaps with a notion of giving some protection to the exposed surfaces. The chief protection given this way is from observation, by making the wound less conspicuous; so

far as the cambium is concerned, it is ruined by this treatment. More conscientious people wind a cloth about the injured spot. This generally favors the growth of molds, which spoil the chance of regeneration. The treatment most likely to result in healing is to leave a wound of this kind absolutely alone. The warmer and the drier the weather at the time the greater appears to be the chance of healing by regeneration of bark all

Fig. 16. The temporary "subordinate" cion should be kept smaller than the permanent cion, by frequent heavy pruning, so that when it is removed the wound will be small and will be healed quickly (left and center). Figure on right shows a case in which the subordinate cion (the one pointing toward the camera) is being developed into a small lateral branch and will not be removed.

over the wounded area, if the exposed surface is not touched. This is quicker and more satisfactory than healing by callus formation (Fig. 18).

On trees which have been ringed within one or two or even three years after planting, the advisability of bridge grafting is doubtful; it will probably be cheaper and in the end more satisfactory to saw them off below the injured area and cleft graft them. Reliance should not be placed in sprout growth under these circumstances. In many cases the trees so treated will

not sprout at all; if they do, many of them will sprout only below the graft and most of these sprouts that do come from above the grafts will be slow in starting and slow in growth. The setting of cions, even though no change in variety is desired results in surer, quicker growth, and, provided the grafts receive proper subsequent handling, induces a more rapid healing and a better shaped tree.

With all these qualifications, however, the cases of real need of bridge grafting are numerous. The cost of the operation, balanced against the prospective or actual capitalized value of an established tree, is generally very small. The grafts grow readily and when the need is indicated the work should be undertaken.

If the exposed surface is at all extensive, it should be covered over as soon as discovered. Some time will elapse before the water-conducting power of the inserted cions equals that of the original sapwood. Fortunately, sapwood with the bark removed carries water in some quantity for a time, sometimes for several years, provided it is protected from drying effects of the atmosphere. This effect is important enough to warrant special effort at keeping the sapwood moist, even though the grafting is not to be done for some time. Drying severe enough to cause checking of exposed sapwood on live trees occurs in March or April. If the wounds are low enough to render it practicable, mounding with earth serves satisfactorily as protection against drying. If the wounds are too high, or are made when the ground is frozen, adequate coverage can be secured on apples (not on stone fruits) by painting on a warm mixture of five pounds resin and three-eighths pint of raw linseed oil. For use when warm weather is assured the linseed may be reduced to one-fourth pint.

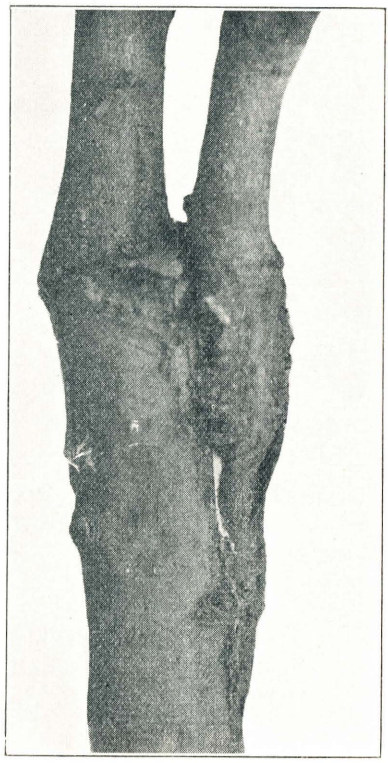


Fig. 17. The cion feeds the stock. The cion on the right made contact on its right and none on its left. Note the death of tissue in the stock at this point and along the cut edge of the stump.

One disadvantage in mounding sometimes develops; namely, the fact that it often retards slipping of the bark, delaying the period when bridging can be done safely. It is often advantageous, in fact, to remove the soil around the trunk a few days before grafting is attempted, in order to hasten the slipping of the bark, which is usually slower in developing under ground than in the parts above ground.

Bridge grafting is not readily accomplished until the bark on the tree slips well. Before this time, raising of the bark is very difficult and if it is

accomplished at all, much of the inner bark remains attached to the wood. This interferes with the attainment of cambial contact and scraping down to the wood surface is very exacting and laborous. On the other hand, grafting much later may be reasonably successful. Damage from mice or from winter injury is sometimes unnoticed until attention is drawn to the injured tree by a yellowish tinge of the foliage in June. In such cases, as an emergency measure, bridge grafting may be done in early summer. Bridge grafts spanning old injuries in mature apple trees at East Lansing and in

Fig. 18. Two kinds of wound healing. On the right the cambium was not destroyed and bark regeneration occurred directly on the wood; on the left the cambium was destroyed and healing is accomplished by the slower process of callus growth from the edges.

young apple trees at Cheboygan, made in the first part of July, were very successful. For this summer work, however, careful selection of cion wood is necessary. There is, ordinarily, no special advantage in summer grafting of this type and it is recommended only as an emergency measure.

Cion wood for the bridge graft is of the same character as that used in other grafts, so far as age and vigor are concerned, but special effort should be made to secure large cions. For summer work, the wood of the previous year should be used; at this season, the basal portion of the wood of the current season can be employed in default of satisfactory older wood, par-

ticularly if it is ringed a week or two before it is cut. Since fruiting wood will not ordinarily be developed from bridge grafts, the variety from which they are taken is of no consequence, except that hardy varieties such as McIntosh or Snow should, other things equal, receive preference and Baldwin, King, and Grimes be avoided. With this single qualification, attention can be concentrated on securing the best cion wood, regardless of the variety.

Good condition of the wood surface of the tree at the points of contact with the cions is very important in bridge grafting. Microscopical examination of sections through several bridge graft unions made in the laboratory of the Horticultural Department indicates that a large part of the callus tissue through which connection is established comes from this wood rather than from the cions. This fact has special application in bridging areas which have been dead for some time, since in such cases the tissue for some distance from the area originally killed may be alive but in such poor condition that grafts set in it will not take well. Whenever it is practicable the tree should be prepared for the setting of the cions a day or two before the actual grafting is done. All dead bark should be removed and, if the wound is old, any unhealthy live bark should be removed. Unless the injured area extends for such distance on the trunk that the securing of cion wood of sufficient length is difficult, there is no special need of pains to keep the bridge area short, as proper unions can be made more easily with long cions than with those which are very short. The exposed surfaces on apple trees should be covered with resin-linseed paint up to within an inch of the edges. If only a small amount of work is to be done, grafting wax, may be used, but it is too expensive for extensive operations. The purpose of this protection is two-fold; it is to guard against invasion by wood-rotting fungi and to keep the sapwood from drying out.

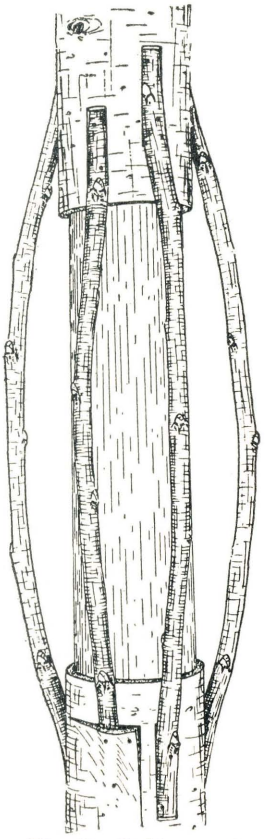


Fig. 19. Bridge graft, showing some of the many methods of setting cions. Note the spring on the cions. This is particularly important in young trees, which sway most.

The various methods of setting the cions depend in common on securing contact between the surface of the wood on the tree and a bevel or sloping cut on the cion. In some forms of the bridge graft an additional contact may be secured with the bark of the tree, but this is by no means essential.

Dependence on contact through a bevel cut on the cion practically necessitates a spring or bow in the cion as it is finally set (Fig. 19). An additional advantage of the spring is the provision of a small amount of slack which will permit some swaying of the tree without disturbance of the union. If the cion is somewhat curved, the bevels should be cut on the concave side. The spring is secured with a straight cion by cutting it slightly longer than the distance it will cover when set, fitting one end in position, securing it by one or two No. 18 wire

nails with slender shafts and wide heads, and then springing it into place and nailing it at the free end. If the cion is as large and hard as it should be and the spring sufficient, the brads may be set in very slightly to draw the bevel cut close to the wood.

One cion for each two inches in the circumference of the tree will be sufficient.

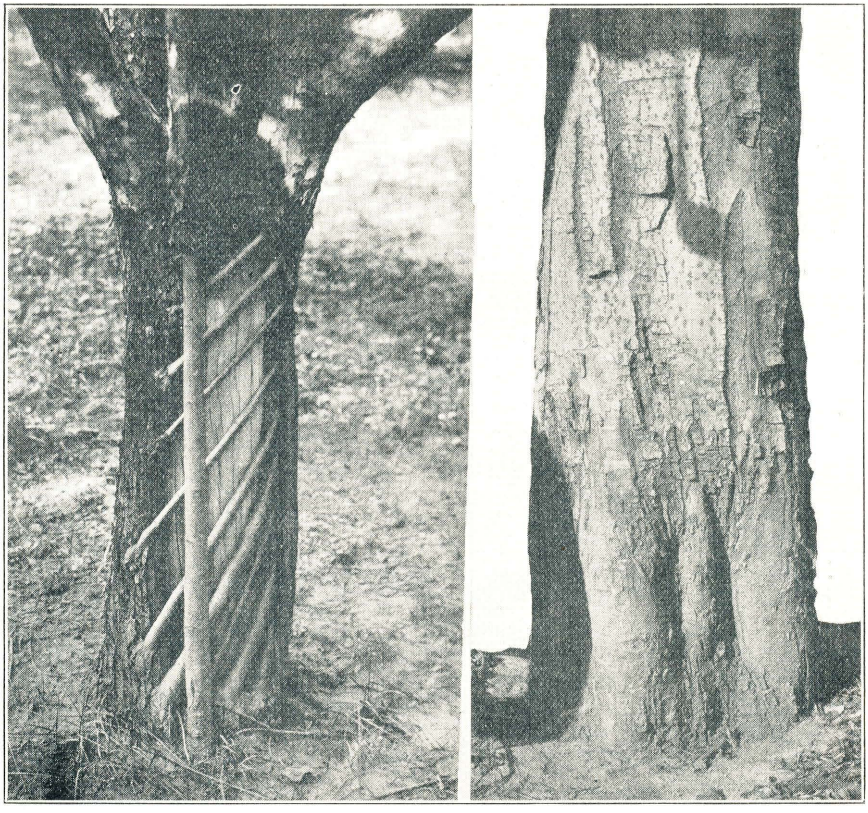


Fig. 20. Bridge graft. Left: Note the more vigorous growth the more nearly vertical the cions are set. Note also the checking in the wood of the trunk; this wood should have been protected before the cions were set. Right: Older grafts.

If the cions available are not long enough to span the dead area, they may in some cases be set diagonally with fairly satisfactory results, but vertical placing is preferable by far (Fig. 20).

Cions should be set "right end up," i. e., as they grew on the tree, but, if through inadvertance any are set upside down, is it not necessary to replace them. Inverted cions have been observed growing in considerable numbers.

The simplest and, where it is feasible, the most easily made union involves an L-shaped cut in the bark (Fig. 21). Below the wound the L is inverted. Each arm of the L is about one and one-half inches in length and

each is cut an inch or two from the edge of the wound. The cion is beveled at either end principally on the side destined to be set against the tree; the other side is beveled sufficiently to give a rather sharp angle to the wedge. The bark in the angle of the L cut is raised sufficiently to admit the cion, which is then inserted and brads driven through the bark and the cion. Nailing the bark is necessary because it is very difficult to bend the

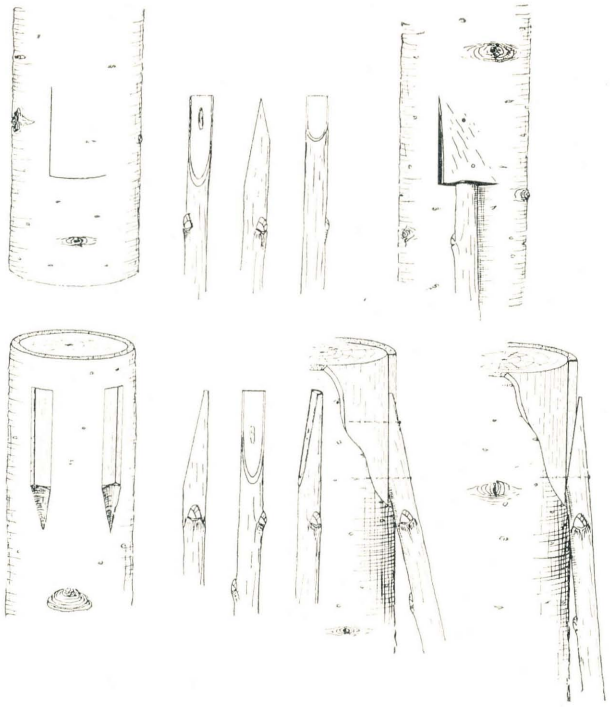


Fig. 21. Two of the numerous methods of fitting cions to stock in the bridge graft. Above: the L cut, with trimmed cion. The long bevel of the cion goes against the wood; the contact is between the cambium surface of the wood and the cambium line of the cion. Below: the inlay, a method suited to trees with very thick bark. The notches below the slots shown on the left may or may not be necessary. On the right: one way to make grafts fail is through a cion somewhat too short and consequent lack of sufficient spring to ensure contact.

bark back sufficiently to set the brad directly into the cion without injury to the bark and because at this season there is a tendency for the bark to shrink wherever it is cut vertically and its great tension relieved. This union is best suited to trees with thin or only moderately thick bark.

For trees with very thick bark or for cases where cions are set into the roots, the inlay graft is preferable. This union has a further advantage in that the ends of the cions are not cut down so thin and they are less liable

to damage from nailing. The bevel cut is very long, perhaps three or four inches, but it does not extend to the opposite side (Fig. 21). With the cion prepared the operator holds one end against the bark at the spot it is to occupy and traces around it with the knife, marking on the bark and the piece just outlined is removed. In thick-barked trees, much time may be saved, at no cost to the tree, by shaving the corky bark where the graft is to be set, leaving the cortex or green bark, against which the mark may be made and in which the slot is cut. The cion is then set in and nailed at this end and the process repeated at the other end. This union requires some-

Fig. 22. New roots for an old tree. Seedlings planted close to the trunk and their tops approach grafted (like the top of a bridge graft) into the trunk. Useful in older cases of ringing, when the roots on one side are dead.

what more skill than that previously described and generally takes more time.

Modifications of these unions are sometimes employed. In very thick barked trees, the cions are sometimes cut to very thin wedges and forced under the bark at the edge of the wound. This method is hard on the cions as the wedge is frequently bruised and short cions are sometimes broken in springing them sufficiently to slip under the bark. Furthermore, the thinness of the wedges makes them more liable to injury from nailing. Some operators slit the bark vertically at the edge of the wound and set the cion directly under the cut so that it raises both flaps of the bark. In this union, however, satisfactory nailing is rather difficult, the flaps of bark make little contact with the cion and proper waxing at the upper end is generally more difficult. Even though the cut is necessary to permit the raising of the bark, the cion should be set under one flap or the other.

Mr. Hootman, of the Extension Service, has been very successful with a simplification of the slot method which effects a material saving of time and should, in the majority of cases, make adequate cambium contact more certain than that often attained with the slot method just described. Where grafting is done soon after the injury occurs (first season) it is preferable. In older cases it is often necessary to go farther from the exposed area; in these cases, according to circumstances, use of the regular slot graft may be necessary, or the best course may be to clear away all doubtful bark and use the simplified method.

This modified method may be described as the open slot. The slot opens directly on the edge of the exposed area as in the second from the left on the upper edge in Fig. 19, but the bark is not removed; it is merely lifted, being cut only on the edges of the slot and "hinged" at the uncut end. The cion is trimmed as shown in the upper row of Fig. 21 and pushed under the bark, and nailing is done through the bark.

Whatever the type of union employed, all cut surfaces should be covered with grafting wax; the brush wax is well suited to this work. Considerable care will be necessary to secure tight sealing in the angle between the tree and the upper end of the cion, as the wax must be applied and set against the downward pull of gravity. For this work it may be stiffened somewhat by cooling on the brush. Wedging a small, loose ball of paper in the angle may be helpful; the brush can then reach all the surfaces and a complete coating of wax can be applied very readily. The edges of the ringed area also should be covered.

As soon as grafting and wound covering are completed, soil should be replaced and in fact raising a slight mound may be helpful, since mice have sometimes returned to attack newly set bridge grafts. This filling should be done with some care, lest clods of earth displace the newly set cions. Occasionally, the extra moisture thus ensured induces rooting in a cion (particularly in Spy) which has failed to unite at the base, and thus prevent its becoming an entire loss.

GRAFTING A NEW ROOT TO AN OLD TREE

The progress of fire blight cankers on tree trunks, or extensive collar rot, or trunk injury of long standing effecting a partial ringing, may lead to the death of some of the roots. This in turn is likely to be followed by the death of limbs originating in direct line on the grain of the wood, generally directly above the injury but sometimes, in trees with twisted grain, several points of the compass to one side. In any case, death and subsequent rotting of any considerable portion of the roots weakens the anchorage of the tree in the soil and may lead to its leaning or falling over.

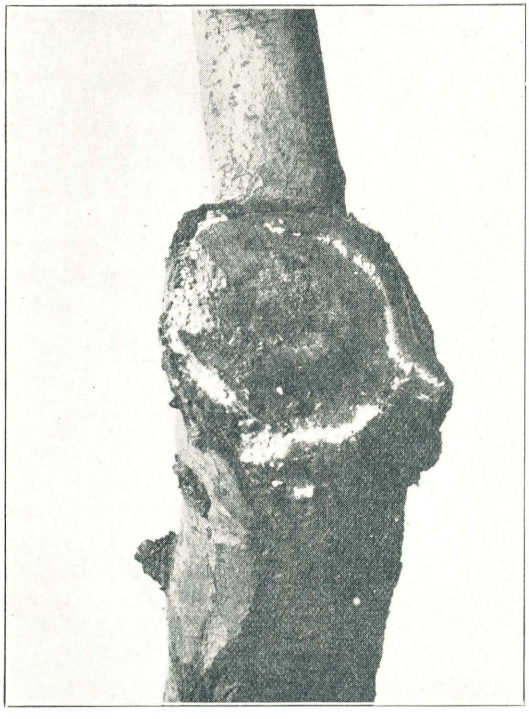


Fig. 23. The invariable difficulty in handling large cuts on the main axis is the failure of callus to form on the "heel," or the side opposite the remaining branch. Note the callus formation on the upper edge of the cut and its absence elsewhere. The wooly aphis display is incidental.

Under these conditions, trees rarely form new roots to replace those lost, because the main body of the stump itself is generally involved. However, young trees set in the soil close to the old tree and connected with it by grafting the top in like the upper end of a bridge graft, form new roots with great rapidity (Fig. 22). As a preliminary measure, obviously, in case the injury has been caused by fire blight all the diseased area should be scraped and disinfected. The actual graft union can be made by any of the methods used in bridge grafting. Seedling trees can be used for this purpose. One year seedlings, as secured from wholesale nurseries, are rather small, but two year seedlings are generally large enough. If budded or grafted trees are used, preference should be given to hardier varieties such as McIntosh, Snow, and Tolman if blight is not present.

Injury to the trunk or collar may have been followed by the growth of suckers, or water sprouts, from below the injured area. If these are of sufficient length, they may be grafted into the sound wood above the injury, remaining attached below.

THE BARK GRAFT

The bark graft is described here because of its applicability to one special purpose. Its use in place of the cleft graft is preferred by some operators, because of the ease of securing a "take" and because it does not involve splitting the stub. This last feature is said to favor more rapid healing and to permit the grafting of stubs too large for splitting. It is questionable whether any kind of graft will consistently make a sound union on stubs too large for cleft grafting and it is certain that bark grafts—particularly on large stubs—are blown out very easily by winds of no extraordinary violence. It cannot be done advantageously until the bark slips. This graft may prove preferable with some stone fruits to secure the greatest percentage of "takes", but it is not ordinarily necessary in the apple.

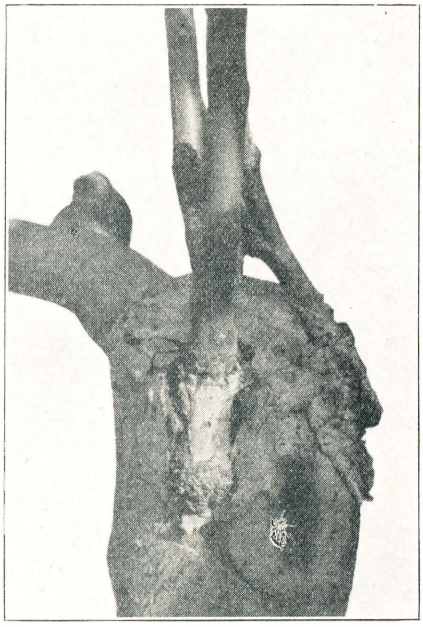


Fig. 24. Cions set to keep "heel" alive until wound is healed over. Bark graft used.

The one case in which the use of the bark graft is recommended in the apple is in prevention of the dieback that usually follows the cutting of a large limb back to a side branch. This dieback is distinct from the sunscald that in many cases follows the sudden and extensive opening of the tree. It is of the same nature as that already described as a consequence of the failure of one cion on a large cleft grafted stump. The heel of the cut is removed from the zone of ready food supply and so forms little or no callus (Fig. 23); it generally dies back more or less and opens the way for decay involving the whole branch. One or two cions inserted at the heel will supply the material for callus formation and thus keep this area alive and assist in healing the wound over (Fig. 24).

Obviously, these cions should not be allowed to grow rampantly else they will be likely to break out or they will in many cases recreate the high or crowded top the cut was made to remove. Pruning back will keep them within bounds and at the same time permit them to be of real service in healing the injury.

The bark graft for this purpose may be made very much the same as the lower end of the inlay bridge graft, except that the bark removal starts at the edge of the wound (Fig. 25). Sometimes the cion is cut to a shoulder or it may be cut with a plain bevel. Wrapping with waxed cloth to hold the cions as is commonly practiced in bark grafting would be awkward on account of the presence of the side branch; each cion may be secured with two brads or thin small wire nails as in the bridge graft. Wax should be applied as in the other grafts, to all cut surfaces.

At the South Haven substation, bark grafting has been used very successfully for several years in top-working pears, but less successfully with apples and cherries. In this work, a procedure differing from that just outlined has been used. Instead of the slot shown in the diagram, a single slit is made. The bark along this slit is raised slightly by the insertion of a thin and rather narrow smooth hickory wedge. The cion, trimmed with a rather

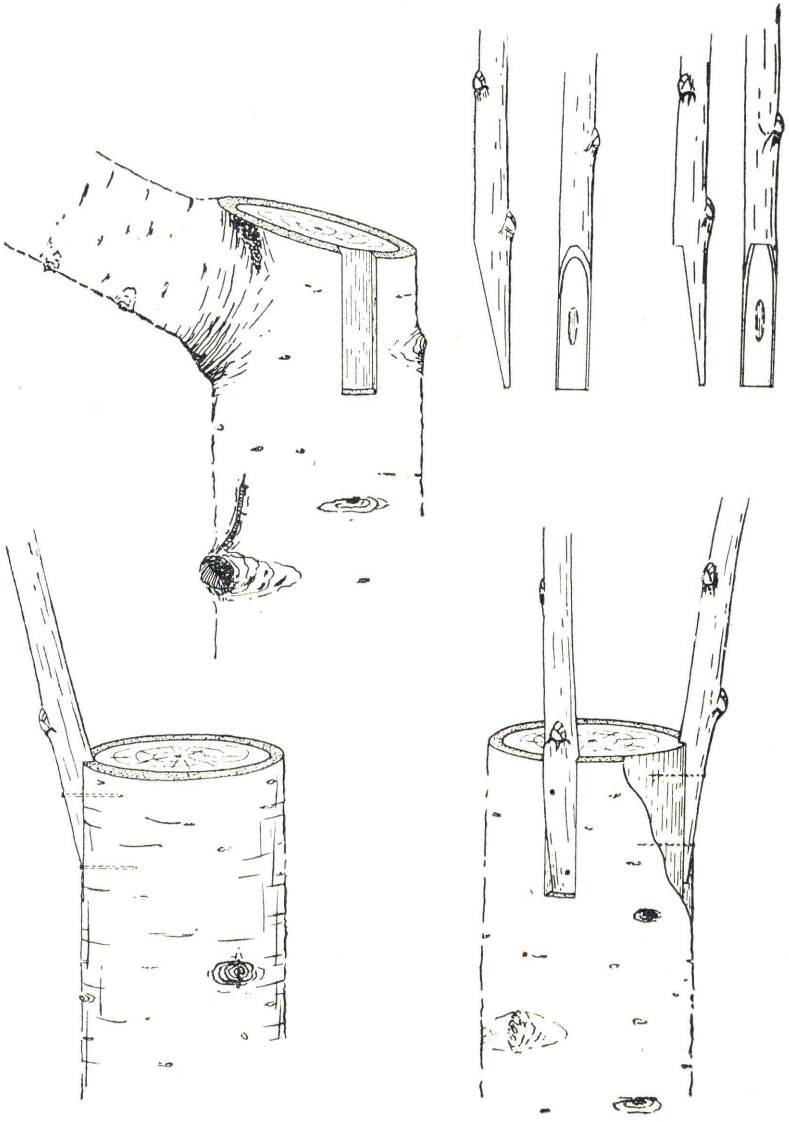


Fig. 25. The operations involved in bark grafting. For the sake of clearness the slot is shown too near the side limb to give full benefit to the "heel"; it should be opposite the limb. Cions may be set with a plain bevel or shouldered. This graft is not recommended for regular top-working, since the cions blow out too easily.

long bevel on one side (the side to be pressed against the stock) and with little more than the bark removed on the other side, is then inserted inside the wedge and the wedge is withdrawn. Two winds of grafting tape to hold the cions and bark in close, followed by waxing, complete the operation. The principal advantage gained by this method is speed; the "take" is high and on pears at South Haven the wounds heal well. On apples at East Lansing, repeated trials of several methods have failed to secure good enough contact at the top of the stub to produce good healing of the wounds.

TOP-WORKING

Though of course the primary object in top-working a tree is to change the variety of the fruit borne, satisfactory attainment of that object depends on several details. First, the unions must be sound; second, the new fruiting wood must be reasonably close to the ground; third, the tree must not be exposed to sunscald during the process; fourth, the change should be made with the setting of the smallest number of grafts that is consistent with good results.

Soundness of union depends largely on care in the actual making of the grafts and in the treatment they receive subsequently as already discussed under the "Cleft Craft".

Keeping the new fruiting wood low depends partly on setting the grafts for the main fruiting limbs as low as possible and partly on the subsequent pruning. Anxiety to gain lowness of head should not lead to the cutting back of limbs to large stumps, because the soundness of the union is thereby menaced.

Low fruiting wood, protection against sunscald and the setting of the minimum number of grafts are more or less interdependent and should all receive consideration when top-working is undertaken. Of the three, perhaps protection against sunscald is the most important, as it is concerned in high degree with the soundness of the tree. It is in itself of less consequence than the disorders which are likely, or, in a majority of cases, sure to follow it. Among these are flat head borers, which make still easier the entrance of wood-destroying fungi, producing eventually a hollow heart and finally a broken limb. Even without the borers these fungi gain entrance through the sunscald lesions. An injured area of this sort is almost certain to be invaded sooner or later by the black-rot fungus which will in time girdle the limb.

Sunscald is likely to occur when any considerable portion of a smooth-barked branch is exposed directly to the sun, particularly from noon to two or three o'clock. The more nearly at right angles the sun's rays strike at this time the greater the likelihood of damage. The larger limbs with smooth bark are, despite their thicker bark, as likely to suffer as the smaller, because the greater curvature on the surface of the smaller limbs increases the reflection of heat and thereby diminishes the absorption. As specific example of the difference, it may be stated that at noon on a limb pointing due north the sun's rays are striking a point one-half inch from the top of the circumference as follows: on a limb two inches in diameter, at an angle of 60 degrees and on a limb six inches in diameter, at an angle of 85.2 degrees. Some of this injury may occur in winter, but most of the sunscald in the top of the tree originates in the summer. Analysis of these con-

ditions indicates that moderately large limbs leaning to the north and northeast are most subject to injury; this is confirmed by field observations.

If the whole tree is top-worked at once, much or most of the small wood which bears the foliage is removed and the sun's rays admitted freely to the bark of the northward-leaning branches. Under these conditions sunscald is likely to develop. Its onset is sometimes slow under Michigan conditions. The first year's scorching may be confined to the outer bark, the next year's extending somewhat deeper and so on. There are, however, numerous examples of very bad cases developing in one year.

Fig. 26. Grafting a strong growing variety on a weak growing variety, (as Rhode Island Greening on Duchess) may throw undue weight on small crotches, causing breakage, not at the unions, but at the crotches.

As a safeguard against sunscald, then, top-working a tree should be spread over two years. In the first spring, the work may begin on the northeast side and embrace about half of the tree (Fig. 27). The stubs grafted at this time are shaded by the branches still untouched, and they are thus protected against injury. During the first summer, water sprouts generally grow out in considerable numbers on the grafted limbs. Of these, those that are so placed as to shade the limbs should be retained. If they

are pinched back when six or eight inches long, they will branch and increase the shade. In any case, they can be kept small by cutting back in the spring. The remainder should be removed during the summer or in the following spring; those utilized for their shade can generally be removed in the third spring.

In the spring of the second year, the top-working may be completed (Fig. 28). The water sprouts and the growth from the cions should provide, from this time on, sufficient shade for the limbs on the north side. Therefore, grafting the remaining limbs may be done with no danger of sunscald on those first grafted. Since these remaining limbs have a more

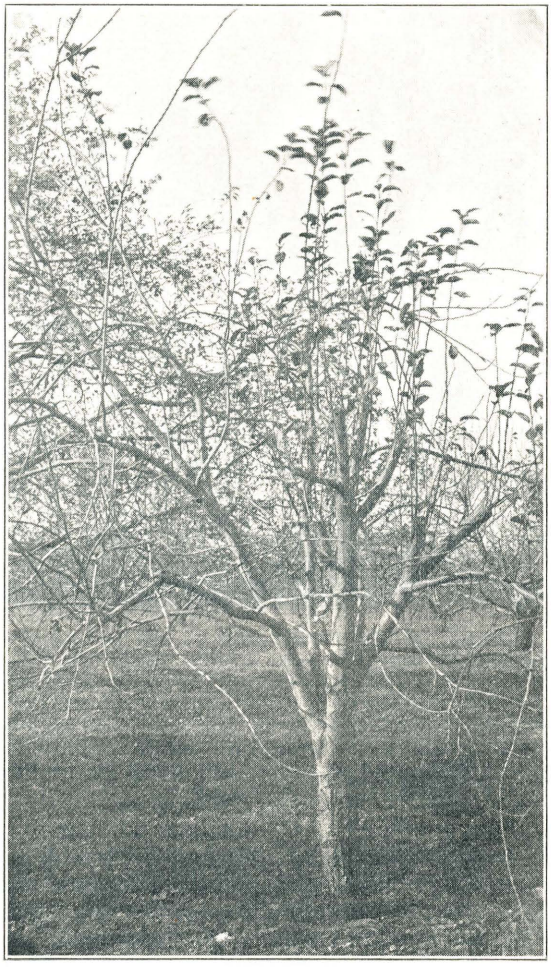


Fig. 27. A top-worked tree at the end of the first season. Vigorous growth of cions and water sprouts; some of these water sprouts will be retained for a time to shade the limbs. Note the limbs left on the southwest side to provide shade.

or less southerly inclination, they receive the rays of the sun during the warmest weather at a very acute angle, so that more heat is reflected and less absorbed. Not only is this true, but in addition, any given area on the limbs leaning southward receives less heat than an equal area on a limb leaning toward the north. Concretely, assuming the sun to be at a height of 60 degrees, a limb leaning north at an angle of 45 degrees will receive a square inch shaft of sunshine on an area of 1.04 sq. inches, while a limb leaning southward at the same angle will receive the same amount of sun-

Fig. 28. A top-worked tree at the end of the second season. The part to the right was top-worked first and has had two season's growth; to the left, the cions have had one season's growth. In this tree cions were set too high (and in too great number) for really economical operation. The purpose in this case was to induce somewhat earlier fruiting of a new variety.

shine distributed over an area of 3.87 sq. inches. Stated in other terms: a square inch of surface on the sunny side of the north limb will receive the equivalent of a shaft of sunshine passing through an aperture of 0.97 sq. inch area in a plane at right angles to the light, while a like area on the south limb will receive only the amount that would pass through an aperture of 0.21 sq. inch area. In other words, the south limb not only receives less but absorbs less of what it does receive. Furthermore, a slight tuft of foliage will shade a greater amount of bark on a south limb, the proportion being equal in fact to the figures given above for the distribution of a square inch

of sunshine. Consequently, the limb pointing south is in far less need of protection against sunscald, and top-working on this half of the tree can be done without fear of injury.

A skillful operator can distribute grafts in various parts of the tree, instead of working from side to side and by setting the cions in shaded places he can do this without great danger from sunscald. However, if only one branch on a limb is grafted, the growth of the cions and water sprouts is likely to be much less than it is when several branches on a limb are grafted at one time. When, therefore, the second year's grafting removes the shading limbs, those that were worked over in the previous year are likely to suffer.

In the spring of 1924, certain trees in the College Orchard were completely top-worked and, to guard against sunscald, on all limbs of any considerable size those areas exposed to sunshine between noon and two o'clock were painted with white cold water paint. This has the same effect, in cutting down heat absorption, as whitewash and it is rather more durable though it should be renewed about July 1. The cutting back of the whole tree at once stimulated a very vigorous growth in the cions and by midsummer most of the limbs were shaded sufficiently by new growth to eliminate further danger of sunscald. Unless the grower is willing to incur this extra labor, however, and to watch the trees carefully, he should distribute the work over two years. Furthermore, it is possible that the story of these trees may have another chapter. The extremely vigorous growth of the cions has left them in poor condition to withstand a cold winter. Consequently, the safest recommendation is to adhere to the plan of distributing the work on each tree over two years. In one season, trees top-worked entirely at once and with no provision against sunscald may thrive just as well as those handled more carefully and they may go through the following winter in perfect condition. This does not guarantee equal success another year and the risk of injury or death is too great and the consequence of injury too serious, to justify careless handling.

The experienced tree grafter can so spot grafts in key positions as to complete in one year all the grafting necessary to remaking the tree without unduly exposing it to sunscald or excessive growth of cions; others should, for a time, follow the two-year plan.

Cions should never be set where they will be heavily shaded; their growth will be meager. As a matter of economy, they should be set only in places where they will have a chance to develop into limbs of considerable size. Small horizontal limbs close to the ground, where they are overshadowed by other better limbs, are often very tempting, because of the ease with which they can be grafted, but they should be avoided. Branches anywhere which, from their position, can never become large, are not likely to be worth the trouble of working over. Unless it be for early fruiting of some new variety or to provide for cross pollination at the earliest season possible, grafts should not be set near the tips of branches which have already extended as far as they are likely to grow.

Top-working of large trees, though possible, is likely to be unprofitable. The main limbs are so large in their lower portions that grafts cannot be set here with much likelihood of good unions resulting. The only wood of proper size for grafting in these trees is very high and so far out on the limbs that only a small amount of fruiting wood can develop from each cion. So many branches must be grafted if the top-working is done here

that the operation becomes very expensive. Furthermore, when grafts are set so high in the branches there is constant trouble from sprouts coming out along the branches below the graft; these must either be grafted in their turn or removed. Grafting of smaller branches low on the limbs and the subsequent cutting of the old limbs back to these branches, a treatment sometimes attempted, is likely to lead through decay starting at the point of amputation, to the final breakdown of the whole branch with the first heavy load of fruit on the new growth. In case the fruit of the old tree is utterly worthless, there is, of course, little but the labor to lose in attempting a renovation of this sort. Even then, however, there is at least an even chance that more satisfactory results will be secured by removing the old tree wholly and planting a new tree.

As a matter of record, it should, perhaps, be stated here that the notion, revived about once in each decade, of cutting off an old tree and setting fifteen or twenty grafts around the stump is usually founded on enthusiastic observation of the first year's growth. The debacle generally occurring, at the latest, about the seventh year, from the blowing out of the grafts, rarely receives mention. The expansion of the grafts extends, naturally, along the cambium of the stumps and as the curvature of this is slight in large stumps the union is almost wholly in one plane so that a strong wind at right angles to this plane is, sooner or later, going to snap the graft or pull it out at this point. If supporting the graft by a stake is attempted, there is still no known means of forcing the callus to grow around and over the stump.

Certain varieties should be grown only when top-worked in hardier or stronger trees. Since this matter, as it relates to hardiness, is treated at some length in a separate publication of the Michigan Experiment Station, reference to it here is confined to the bald statement that Grimes, King, Baldwin, Hubbardston, Golden Delicious, and, probably, Rhode Island Greenings should be grown only as top-worked trees. Tolman Sweet, Snow, Virginia Crab, and Wolf River seem, from available evidence, to be suitable stocks. These can be planted and subsequently grafted or budded without any material setback.

Grimes is now offered already top-worked ("double-worked") by several nurseries. As these trees are sold, they have been top-worked in the main trunk about a foot above the ground so that the whole framework is Grimes. This arrangement will, perhaps, be satisfactory with Grimes, since the injury in this variety is chiefly at the collar, but with the others named as tender, injury in the crotches is almost as common as that in the collar. For this reason it will be safer to let the hardy stocks grow for a time in the orchard and form the main limbs. These can be top-worked in the spring of the third or fourth year after planting, or at this age budding would be practicable. Top-working of Red Canada is done, not because of its lack of hardiness, but because it is a poor grower; in this case, too, the framework should be formed from the sturdier variety. Northern Spy has been favored as a stock on account of its vigorous growth, but cannot be recommended for this purpose because it is not perfectly hardy, and if it is grafted in the limbs, its acute angled crotches offer difficulties.

Though it is questionable whether any true uncongeniality exists between apple varieties, simple mechanical peculiarities render some combinations undesirable. In general, it is dangerous to put coarse-growing varieties such as Spy and Rhode Island Greening, on weak-growers such

as Wagener and Duchess (Fig. 26). If this is done, the coarse-growing cions develop into limbs too heavy for the crotches of the weak-growing stocks and breaking occurs, not at the graft union, but at the crotches.

GRAFTING WAX

The kinds of waxes that have been used in grafting at some time or other are very numerous and very diverse, ranging from the mixture of chopped straw and blue clay on one hand to rather complicated kinds for special purposes. Occasionally, good results have been reported from paraffin, from ordinary fly paper—though these have sometimes proved injurious—and even from adhesive tape. The fact that such diverse materials are occasionally successful indicates that they meet certain fundamental requirements in some degree; the fact that they are not uniformly successful indicates deficiencies that are of no importance at some times but fatal at others.

The ideal grafting wax would have at least these qualifications: (1) it would exclude air and fungi and retain the moisture of the wood; (2) it would contain no material that will injure live tissue in the strength at which it is used; (3) it would not crack in cold weather; (4) it would not run in hot weather; (5) it would be semi-permanent in possession of its various virtues; (6) it would have more or less elasticity, to accommodate itself to changes in dimension of stock and cion consequent upon growth.

No wax yet devised meets all these requirements perfectly but several meet them well enough for practical purposes under the conditions to which they are ordinarily exposed.

Most of the waxes used soften with heat; some become pliable at the temperature of the hands and are called hand waxes. Others, with a higher melting point, are heated and applied with a brush while warm; these are called brush waxes. In the liquid waxes some solvent, usually alcohol, is used; the wax is applied cold and the evaporation of the alcohol leaves a solid residue.

Formulae for two waxes are given here. These are, in a sense, basic formulae and may at times be varied somewhat to suit special conditions. For example, for grafting very late in the spring, with warm weather, the proportion of resin may be increased; for grafting very early in the season with cold weather still to be expected, the proportion of linseed oil or tallow, may be increased.

The hand wax most likely to be satisfactory under the conditions ordinarily obtaining, is made of resin, 4 lbs.; beeswax, 2 lbs.; tallow, 1 lb. The resin is melted first, then the beeswax is put in and when this has melted the tallow is added. As soon as the tallow lumps have disappeared, the mixture is poured into cold water. When it has cooled sufficiently, the hands having been greased previously with tallow, the mass is worked until it has become readily pliable and easily handled. The first working should be done carefully to avoid burnt thumbs as the mass sometimes cools on the outside while the inside is still very hot. The heat employed in melting the ingredients should not be intense, as melted and vaporizing resin is rather inflammable; if the resin does ignite the flames may be smothered by setting another pan in the pan containing the resin. Over a particularly hot fire, the melting resin gives off a dense smoke.

The use of hand wax in the orchard is not the pleasantest of occupations, particularly in cold weather. The hands must be greased and even then are likely to become sticky, making the change from waxing to other operations awkward. In cold weather the wax requires considerable working unless it is kept in warm water.

Recently, a brush wax has superseded the hand wax in many orchards. This is made of resin 5 lbs.; beeswax 1 lb.; raw linseed oil, ¼ pint; and lamp black or powdered (not "ground") charcoal, one-half pound. The resin is melted, the beeswax added and melted, the linseed oil added, the mixture removed from the fire and the lamp black stirred in a little at a time, to avoid boiling over. This mixture, with the linseed oil added, appears to be even more inflammable than the hand wax mixtures and should be treated accordingly. If, however, it is made over an ordinary fire there is little danger.

As soon as the cooking is completed the wax may be cooled somewhat and used at once. For operations of any extent, however, it is best to prepare the supply in advance. The hot wax may be poured into shallow pans, to the depth of about an inch, and allowed to cool, thorough cooling will take some time; when it has occurred a sharp blow on the bottom of the pan will loosen the wax which can then be broken into small lumps. These small lumps are convenient when a small heating pot is used.

For heating the wax in the orchard, a fairly satisfactory apparatus can be made by perforating a ten quart galvanized bucket on the bottom and side with numerous holes of about ¼ inch diameter and nesting a pan in the top. In the pan the wax is melted and kept warm; below the pan in the bucket two small cans of "canned heat" will provide sufficient warmth under most weather conditions for from one and one-half to two hours. In a high wind it may be necessary to shelter this heater in a box, as the wind is likely to cool the surface of the wax and may extinguish the fire. Furthermore, handling this apparatus in the tree top is rather difficult.

Heating the wax in the orchard may be accomplished in several ways. Heaters specially designed for this purpose, using alcohol as fuel, are on sale. These vary somewhat in output of melted wax and reliability of the flame, some excelling others in one or both respects. Mr. Hootman, of the Extension Service, has used effectively, over wood fires and camp cook stoves, a large metal container, with pressed seams, (10 qt. bucket size) with a tin can (No. 2 size) suspended level with the top. Both contain grafting wax, but generally at different temperatures, the smaller can warming less rapidly over the fire and cooling less rapidly off the fire. An ordinary brush may be left in the inner can without danger of injury to the set of the bristles. Some growers have used in turn two rather large cans, heating one while the other is in use; if the bulk of wax in these is considerable, it remains soft for some time after removal from the fire.

The best brush for applying this wax is about an inch wide. The brush should not be allowed to rest deep in hot wax for any length of time, or the heat will melt the glue in which the bristles are set and they will pull out. This can be prevented by driving a small nail in the handle of the brush and bending it over as a hook for hanging the brush to the rim of the pot, taking due care that it is allowed to hang with the bristles just above the wax. This will bring the nail high enough on the handle so that it does not interfere with manipulation of the brush.

Occasionally, when the wax is applied very hot, there is some injury to live bark, particularly on the cions, where the bark is thin and tender. This

trouble is rarely encountered in practice, where the ordinary types of heaters are used; it is more likely to occur when the wax is heated over rather large fires and applied immediately upon removal. If the wax made by the formula given above does not set at once but is inclined to run when applied, it is probably too hot for safe use.

This brush wax retains its various good qualities longer than any of the hand waxes. It is applied more easily and more rapidly, leaves fewer air holes and though it is harder it seems less likely to crack. In addition, rather less of it is required for a given amount of work and it is, pound for pound, cheaper. Beeswax is the expensive ingredient in any wax, costing ordinarily from six to ten times as much per pound as the resin. This brush wax uses a pound more of resin and a pound less of beeswax in making the six pounds of resin and beeswax combined that constitute the bases of the respective waxes.

The lamp black serves a two-fold purpose. Without it the wax is very sticky, stringing out in long threads with every stroke of the brush. Its black color helps in heat absorption, making the wax pliable though it does not run. This pliability is advantageous in that the expansion of the growing cions is less likely to force the wax loose in large masses; in some cases minute cracks in the wax have been known to disappear after a bright warm day, the wax becoming soft enough to unite again.

Various attempts have been made to devise a cheap substitute for beeswax. Paraffin is sometimes recommended. Though success undoubtedly attends its use alone under favorable conditions it cannot be recommended for general use because of its tendency to crack. During the past season in the College Orchard as a substitute for beeswax in the brush wax it has given fairly satisfactory results. The wax containing paraffin was full of bubbles and seemed rather thin, yet the growth of the grafts to which it was applied was entirely satisfactory. It must, however, be observed under more varied conditions before it can be definitely recommended or condemned.

The spring of 1924 at East Lansing was exceptionally favorable for the "take" or grafts. Seven different kinds of waxes under trial gave uniformly excellent results as measured by the number of cions growing. Distinction between a good and a poor wax cannot be made under such circumstances and must await more trying conditions. For the present, recommendation must be confined to the standard brush wax described above. Some experiments with cold liquid wax (alcoholic) in the spring of 1933 were not encouraging.

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