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PROVINCE OF ALBERTA
Department of Agriculture

UNIVERSITY OF ALBERTA
Faculty of Agriculture

BUDDING AND GRAFTING

BY

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AND

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Brooks, Alberta

Authorized by

HON. D. B. MACMILLAN
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Budding and Grafting^{*}

BY

J. S. SHOEMAKER and P. D. HARGRAVE

INTRODUCTION

Few, if any, fruit-tree varieties reproduce true-to-name from seed. Each seedling is different from its parents because cross-pollination takes place when the trees are in bloom. If a number of apple seeds, for example, are sown, every seedling will differ in some degree from the parents and from each other; hence the Osman crabapple, or any other named variety of fruit, is propagated vegetatively, as by budding and grafting, instead of from seed.

Budding and grafting are not mysterious practices. In fact, the procedure is very simple and does not require expensive equipment. The expert is likely to obtain greater success than the novice, yet anyone can easily learn to bud and graft fruit trees successfully. From the standpoint of the amateur, there is a thrill of satisfaction from one's own efforts; commercially, nurserymen must resort to budding or grafting in order to propagate fruit trees true-to-name, except in some unusual cases. In general, budding is particularly well suited to the propagation of varieties on small seedling stock in the nursery row; whereas grafting is used mostly for top-working trees, though root grafting is used to some extent in nursery work.

STOCKS FOR BUDDING AND GRAFTING

Desirable features in stocks for budding purposes are: $\frac{1}{4}$ - $\frac{1}{2}$ inch diameter near the ground, hardiness, congeniality with the variety to be propagated so that the union is a strong and lasting one, lack of overgrowth or undergrowth tendency, availability, economy, ease of culture, freedom from a tendency to sucker, resistant to blight, a long period in suitable budding condition, give a high percentage of "takes", and adapted to various soils and conditions. Stocks for topworking by grafting or budding should have, besides the features just mentioned, a good habit of branching, with a tendency toward wide or right-angled rather than narrow, V-shaped crotches.

Most stocks on which budding is to be done under Alberta conditions must be grown from seed. Gathering of seed from which stock is to be grown should be limited to the hardiest selections of

^{*}This publication is a revision of University of Alberta Circular 17 on the same subject and by the same authors.

the suitable species. There is great variation, even in the Siberian crabapple and Canadian native plum, in resistance to cold, in vigour, in type of tree, and in date of maturity. Seed from types that ripen their fruit and wood early in the fall will tend to produce similar seedlings.

With most species under Alberta conditions, budding is not practicable in the same year the seed is sown. Usually 1 or 2 years, and in some cases 3 years, elapse before the stock is of a suitable size for budding. Seed may be sown in frames or directly in the nursery rows. After-ripening of the seed is necessary with many species, especially for spring sowing, and there are wide differences between species in the time required before the seed will germinate and do so timely. For the amateur, seeding in the fall directly to the nursery row or frame is the easiest and often most successful method of after-ripening and obtaining good germination the first year. Further information on this subject is available in University of Alberta Circular 21 on "Propagating Trees and Shrubs from Seed".

Stocks for apple and crabapple.—For budding apple and crabapple varieties, seedlings of the Siberian crabapple and of its hardy derivatives such as Columbia, Garnet, and Osman, are satisfactory and best for Alberta conditions. The hardy hybrids have the advantage of larger fruit and larger seed. It is easier to harvest the fruit and to extract the seed from the larger, hybrid forms than from the quite small, berry-like fruits of the Siberian crabapple. Such seedlings are used predominantly for propagating standard varieties in the nursery rows.

Stocks for pears.—Here, as with apples, seedlings are most commonly used as rootstocks in budding.

For greater uniformity than with seedlings, some success has been obtained with root cuttings of Ussurian Pear (*Pyrus ussuriensis*). Roots $\frac{1}{4}$ - $\frac{1}{2}$ inch diameter are used. These are cut into lengths of 3-4 inches and set in an upright position with the upper end $\frac{1}{2}$ inch below the surface of the rooting material.

Ussurian pear, a hardy species, is favourable for hardy pear varieties, and seems to be highly blight resistant. Some varieties which have Common Pear (*P. communis*) ancestry are very vigorous growers and when topworked on Ussurian Pear tend to develop bad overgrowths at the place of union which usually breaks as growth continues. This is particularly true of the wilder forms of Ussurian pear.

Pears can be worked on Siberian crabapple seedlings. The buds and scions take well, but the union is not, in most cases, a good one. If the 1-year-old whip reaches a good size the tree may be planted deeply enough to allow its own roots to develop from above the union and a normal tree will develop. In many cases the transplanting results in a setback so severe that the scion growth dies before becoming established.

Stocks for plum and sandcherry.—Plum seedlings of *Prunus nigra* (Canadian native plum) and *P. americana* are the chief hardy stocks for plums, plum hybrids and sandcherries. *P. americana* is more easily worked than *P. nigra* but the latter is more sturdy. Success in budding plums has not been as good as with crabapples under Alberta conditions, and serious problems still confront the nurseryman in propagating hardy plums.

Sandcherry stocks are useful for its hybrids of small stature but less desirable than plum roots. Large plums worked on sandcherry are subject to blowing loose in the ground. The advantage of working plum on sandcherry or vice versa is the ease with which the suckers from the stock can be distinguished. Sandcherry on sandcherry is not satisfactory because of the difficulty of distinguishing sucker growth. When plum is worked on sandcherry there is a tendency for the stock to sucker badly.

Stocks for sour cherry.—Varieties of the Morello type, such as Wragg, English Morello, Moscow, Bessarabian, Vladimir, Lutovka, Coronation, and Ostheim, take well on the rather tender Mahaleb and Mazzard rootstocks. If the seedlings are planted deeply after being budded, they sometimes develop their own roots. The Dominion Experimental Farm, Morden, Man., reports favourably on the use of *Prunus japonica* as a stock for sour cherries.

Stocks for apricots.—A number of promising apricots, such as Manchurian forms and Hansen hybrids, are available. They are best budded on other hardy apricots but the supply of such seed and seedlings is very limited at the present time. This shortage will likely soon be overcome by saving seed from the many seedlings now approaching fruiting age. Plum has been used temporarily as a root-stock for hardy apricots but is not satisfactory as a "permanent" stock. The "Catch" on the stocks has been good, the buds taking well and growing vigorously, but, the apricot part becomes much thicker in diameter than the plum root-stock and, the union of tissues being poor, the two tend to grow apart rather than to combine. Death results and is due to complete severance of the tissues in the standing tree or to breaking apart of the union by wind as mechanical means. Sandcherry is somewhat more satisfactory than plum as a stock for apricot, but leaves much to be desired.

By the double working of plum and sandcherry to the apricot hybrids Yuksa or Morden 800, good unions can be obtained and if hardy apricot seedlings are available this system of double-working may be worth while.

Deep planting of apricots budded on plum and sandcherry sometimes encourages the formation of apricot roots above the union. If this occurs a strong tree will develop. Support for the trees with heavy stakes until the trees become established is necessary, but the loss of trees usually is heavy on plum root-stocks.

Miscellaneous fruit stocks.—Pincherry can be used for pincherry, but is not congenial with other fruits. Chokecherry, Mayday tree

(*Prunus commutata*), and plum trees can be worked on one another with partial success, but the union is not long lived. A similar situation arises with the budding or grafting of apple and pear on mountain ash, saskatoon, hawthorn, and cotoneaster.

Prunus japonica is a useful stock for hardy sour cherries, Nanking cherries, hardy plums, sandcherries, and sandcherry hybrids. It is not a congenial stock for apricot or pincherry, though a good catch of buds is obtained. *P. japonica* has also exhibited its drought resistance and stimulates fruit-bud development on young stock.

Stocks for roses.—For garden roses the stock most commonly used is *Rosa multiflora japonica*. *Rosa canina*, Dog Rose, is a good stock for garden roses but, unfortunately, the seed requires about 2 years of after-ripening for a high percentage of germination; if otherwise planted perhaps only 1 per cent may germinate the first year and low percentages for a number of succeeding years. *Rosa rugosa* is used in some cases for the propagation of certain forms of roses.

The use of wild roses as understock for cultivated roses has been tried on several occasions. Our wild roses make a good union with the bud but the suckering habits are a strong objection.

Stocks for other ornamentals.—By grafting selections (often on more vigorous and non-suckering stock), great improvement has been brought about in size of panicle, early age of bloom, color, and reduction in amount of suckering of Common Lilac varieties, and a long list of named lilacs is available in the trade. When grafting is practiced, stocks for lilacs include green ash, and other lilacs such as *S. Josikaea* and *S. villosa*.

A number of ornamental forms of Caragana, such as the Fern-leaf Caragana and Weeping Caragana may be grafted to advantage at a height of say 3-5 feet on Common Caragana standards.

The Koster Blue Spruce, Cutleaved Weeping Birch, and a number of other ornamentals are propagated in the nursery by budding and grafting.

BUDDING

Budding is a very useful method of propagating horticultural plants in cases such as follows: (a) to reproduce varieties which do not "come true from seed"; (b) to secure better plants by the use of hardier and more thrifty roots; (c) to overcome certain limitations, as failure to root readily from cuttings or to respond well to grafting; (d) to change the rate of tree growth, as where dwarf trees are desired; (e) to obtain the greatest number of trees from a given quantity of material (just one bud is inserted, instead of the several on grafting scions); (f) to permit multiplication of a variety in the summer; (g) to encourage low cost of nursery trees; (h) to topwork trees in certain cases.

1.—Shield or T-Budding

When to bud.—The best time for T-budding is in the summer when growth is active, the bark “slips” well or “lifts” easily, and the buds of the current season are mature enough to use. The point of parting of the bark from the wood is the cambium (the layer of tissue between bark and wood whose function it is to lay down the two tissues). It is the same layer that parts when the bark is slipped from the wood in making a willow whistle. The season during which the bark will slip varies from year to year. In Alberta the budding season usually starts in mid-or late July. It is seldom successful later than the third week of August, except perhaps under irrigation. Plum, cherry, apricot, pear, and apple slip and set their bark in the order mentioned, and are usually budded in this order in Alberta. The end of the budding season is usually determined by the condition of the bark. When it will no longer slip easily and cleanly no further success is likely. Budding is usually done a little earlier on transplanted stock than on seedlings grown directly in the nursery row.

Buds and budsticks.—The budsticks are taken from the new growth of either orchard or nursery trees of the desired variety. They should be selected in accordance with the size of the seedlings, i.e., the smaller the seedlings the smaller in diameter should be the budsticks selected. Immature or poorly developed buds which are often found at the tip and basal portions of shoots should be avoided; the first few buds at the base of the budstick as well as immature buds from the tip of the twig are usually discarded. There is little or no danger of the leaf buds becoming too mature for budding in a given season.

Terminal growths on branches throughout the tree are the usual sources of budsticks. Watersprouts, and suckers arising above the original point of union, usually have buds that are too immature for T-budding under Alberta conditions, otherwise they are suitable.

The leaves on the budstick are clipped off immediately to prevent water loss. About $\frac{1}{4}$ inch of the leaf stalk is left to facilitate handling the buds. Longer leaf stalks make tying less convenient. If the budsticks are not to be used for several days, wrapping in moist cloth, or in moss, and placing in a cool location, or setting the butts in water helps to prolong their usefulness. Protection from drying out of the budsticks is also advisable and usually necessary while budding is in progress. A wet or damp gunny sack is convenient for this.

Transporting and shipping budsticks.—For transportation, a good plan is to enclose the budsticks in several folds of moistened newspaper and a covering of damp burlap. For shipment, the outside cover should be dry, but the same general plan as just outlined should be practiced. The budsticks are often packed in moistened moss, but such moss-packed material frequently begins to heat before reaching the destination.

Fig. 1.—Shield-budding. Above: T-shaped opening; cutting the bud; inserting the bud. Below: Bud inserted; tied with raffia.

Where to bud.—In budding nursery trees, the work is done close to the ground. The leaves and small branches on the seedlings are rubbed off ahead of the budder to a height of 6-8 inches from the ground to facilitate the operation. If the leaves are removed long before the budding operation the bark may dry and become hard. During hot weather the cleaned stock should not stand more than an hour before budding. This time can be extended without harm on cool damp days. Seedlings about the thickness of a lead pencil are best for budding. Placing the bud on the side exposed to the prevailing winds encourages a straight trunk. Other things being equal, there may be least tendency to drying out of buds on the north or northwest sides (those shaded the most).

The T-shaped opening.—This is made through the bark with a sharp knife. Making the horizontal cut first is preferred (sometimes at an angle of 45°). It is made by a rocking motion of the knife. Then to make the vertical cut, about 1 inch long, the knife is drawn upward slightly to loosen the edges of the bark. Here an advantage of a straight-pointed knife over a curved form is apparent, for the latter could not be twisted to open the bark without forcing into and injuring the tender tissue beneath. If the perpendicular slit is too long, drying out may occur, and if too short inserting the bud is difficult. The depth of the cut is to the cambium, so that peeling readily occurs. Work the edges of the slit loose carefully. Some have thought that with an inverted T-cut there is less chance of water getting in beneath the cut but, as a rule, the erect T-cut is equally good.

Cutting the bud.—A bud is cut, with a shield-shaped piece of bark and a thin layer of wood under it, from a budstick. The cut is made from below with a single drawing motion of the knife. The top of the stick is held so that it points toward the budder. Retaining the entire thickness of the bark when cutting, at the point of the bud, keeps it from crumpling when inserted into the stock. A much thinner amount of wood accompanying the bud is retained with fruits than with roses or nuts; yet, the bud must not be so thin that the soft growing tissue between the bark and the wood is injured. It is unnecessary to remove the thin strip of wood immediately under the bud and as a rule it does not influence the success of the budding operation. With roses and nut plants a thin layer of wood under the bud may tend to prevent the bud from drying out.

At times the stock is very fine or has light bark and will not hold the bud if the heel of wood is left inside the bark. Then it is an advantage to remove the heel. This wood is removed by a sharp pull and a twisting movement at the upper or lower end. The bud and wood should be examined. If the wood has not been properly removed a small hole will be seen on the inside of the bark and the wood will have a tiny, sharp but brittle knob on it which is called the "eye" of the bud. If correctly taken away, the wood will not have this projection, and the base of the bud when examined from

the inside of the bark will appear filled up. Do not handle the bud any more than is necessary or let it dry off. If there is danger of this, hold it on the tongue until ready.

Inserting the bud.—The bud is held with thumb and forefinger by means of a leaf stalk, lifted carefully from the wood without tearing, and is then slipped downward under the loosened flaps of the perpendicular slit of the T-shaped opening so that the bark of the stock envelops it and the cambium tissues are brought together. If the bark of the inserted bud protrudes above or beyond the horizontal part of the T-shaped slit it is well to cut it off there.

Tying.—The bud is wrapped securely, above and below, with raffia, rubber strip, or other suitable material. Raffia, cut into lengths of 18-20 inches and moistened is only fairly satisfactory. Raffia tends to loosen on the wood as it dries, leaving the binding too loose; when the bud is not held firmly, drying results. Some recommend the use of dry raffia for tying but it is difficult to use and is slow.

Rubber strips are probably the best, and now the most widely used wrapping material. Such strips are very easily applied and will not injure the plant. As the stem grows, raffia may damage the stem if not cut off at the proper time. Rubber stretches a certain amount with growth and usually rots away about the time wrapping is no longer needed. Ordinary 2-inch rubber bands are usually obtainable, or narrow strips cut from inner tubes may be used; good elasticity is necessary; rubber bands should not be old.

Rubber strips are obtainable from rubber manufacturing companies, especially prepared for budding purposes. They come in lengths of 3½-5 inches and in widths of 3/32-½ inch, and in gauges according to strength desired. For apple and plum stocks a band 4 inches long, ⅛-inch wide, and .031 inch gauge is satisfactory. There are about 1,700 such pieces in a pound. Rubber bands have the following advantages: (a) exert an even, firm pressure; (b) expand with the plant as it grows; (c) afford greater protection; (d) deteriorate in 3-4 weeks and avoid the necessity of cutting (this is not always the case and the stocks should be watched or growth will be checked); and (e) are easily and quickly applied.

Winding must be done tightly, to keep the bud in place and air-tight. Waxing is usually not necessary or practised, but under dry conditions an application of paraffin wax over the bud, after tying, will give a better catch. Petroleum jelly or vaseline may also be used for this.

Propagators in North Dakota find that hilling plums 6-8 inches with soil not more than 3 weeks before budding aids in giving a bark that slips easily, especially with plums. The bark tightens or sets if the hilling is done at an earlier time. An assistant removes the soil from around the stock 4-6 feet ahead of the budder.

Cutting the binding material.—The bud remains more or less dormant until the following spring. However, the buds should be inspected in about 10 days or two weeks after budding and the binding material should be cut, unless it is self-breaking, on the side opposite the bud, to prevent girdling. The use of rubber bands in tying usually eliminates the need for subsequent cutting. In successful union the tissues heal, the bud has a plump healthy appearance, and the stalk abscises as in the case of a matured normal leaf. In unsuccessful union the bud dries up. Where union failed there may still be time to bud again near the place of the first effort by the same method, or later using the Plate-bud method (or the stock may be whip-grafted next spring).

Cutting off the seedling stock.—The following spring the stock is cut off just above the bud, with a cut sloping down from the bud, and thus forcing the bud into rapid growth. The stock should be cut back before the stored reserves of the root are used up by leaves and twigs. Delayed removal of surplus stocks after growth commences in spring results in weaker growth from the bud regardless of when budding is done. The cut usually is made as close as possible to the bud without causing injury ($\frac{1}{4}$ - $\frac{3}{8}$ inch above the bud), in order to assist rapid healing of the wound. In some cases it is desirable to cut off the budded stocks above the inserted bud leaving 6 to 8 inches of the old stock. This piece of the old stock has the soft new growth from the bud tied to it and serves as a support. Under extremely dry atmospheric conditions cutting the stock directly above the bud has a dwarfing effect. Due to drying, the wound does not usually heal over as well as when a piece of the stock is left, and the extra operation is advantageous so long as not left too long. As soon as the "whip" has developed sufficiently to stand by itself the stub of the old stock is removed by cutting it off just above the growing bud. Obviously, this practice adds to the cost of propagation in large nurseries but may save loss of trees and deserves special consideration by a person propagating only a few trees.

During the early part of the season, some attention may be needed to prevent smothering of the bud (by sprouts arising out of the seedling around and below the bud), to shape the tree by pinching out laterals so that strong branching will occur, and to train the young shoot into upright growth.

With good growing conditions the whip will make a growth of 2-5 feet during the first year after budding and the wound caused by removal of the top of the stock will have healed over.

Digging.—After a year's growth, the budded tree may be dug. Young trees at this stage are known as "whips" and are recommended for planting. The nurseryman may prefer to dig in the fall and place in storage bins over winter, where the whips will not be subject to winterkilling and will be ready for early delivery in the spring. In many cases, it will be more convenient to chance

winterkilling and leave the trees outdoors until time for transplanting in the spring.

2.—Plate or Dry Budding

This method of budding, sometimes called the Jones' method, has, in recent years, assumed considerable popularity with prairie nurserymen, chiefly because it can be used over a much longer season than shield budding. Plate budding is successful during the spring months and also during and later than the shield-bud season. This advantage arises from the fact that it is not necessary to have the bark slip from the wood of the stock as in shield budding. The bud is inserted behind a flap of bark, cut with a sharp knife.

There are some other merits. It is possible to have suitable nursery stock 5 months after plate budding when performed in the early spring, as compared with the longer period for buds placed in midsummer and which do not commence growth until the following spring. In some cases this may mean the gain of a year's growth. Buds placed on stocks in midsummer are sometimes killed the following winter; injury at that time may be avoided by means of the plate-bud method. Early spring budding supplements summer budding and may be employed to rebud stock on which buds failed to take during the previous summer's budding.

The budsticks should not be allowed to dry out and may be kept in good condition, stored, and shipped, much in the same way as outlined later for grafting scions.

Details of the procedure are shown in Fig. 2. Buds and budsticks are prepared in a different manner from that in shield budding. A section of the bark is sliced from the stock over a length of 1-1¼ inches, leaving it attached at the bottom, the cut being made

Fig. 2.—Plate or dry budding. A—Stock; bark sliced and cut off at proper height. B—Cutting the bud. C—Bud wedged in place under stub of bark. D—Bud tied in place with rubber band.

downward. Only the bark should be cut, exposing the cambium layer. The size of the cut should coincide as closely as possible with the cut surface of the bud. The upper three-fourths of the strip of bark is then cut off (Fig. 2 A).

The bud is cut as in shield budding except that a wedge cut is made at the base (Fig. 2 B). When the bud is put in place this wedge cut makes a better fit under the flap of bark left on the stock (Fig. 2 C). The bud is now tied in place with a rubber strip or moist raffia (Fig. 2 D) and subsequently cared for as in shield budding.

GRAFTING

Grafting differs from budding in that instead of one bud a piece of scion wood of at least two or three buds is united with the stock. Grafting of fruit trees is done in the dormant season or near the time growth of the stocks starts in the spring. Grafting is dependent for success on the same principles that apply to budding: (a) scion and stock must be closely related; (b) the work must be done in such a manner that the cambium of both scion and stock come in contact; (c) it must be done at a season of the year and under circumstances that will cause them to unite as soon as growth starts; (d) sharp tools must be used so that all surfaces will be smooth with no ragged edges.

Purposes.—Grafting is a useful procedure for purposes such as follows: (a) to convert a tree of an undesirable variety to a desirable one; (b) to provide necessary cross-pollination with varieties which would not otherwise set fruit well; (c) to make new varieties bear earlier than they would on the parent seedling tree; (d) to speed the testing of new varieties over a wide range of conditions at a cost lower than that of nursery trees; (e) to produce novelty trees bearing more than one variety of fruit; (f) to overcome poor tree characters, trunk damage, soil differences, root killing, and a number of other factors.

Grafting does not make a tender variety any hardier, nor are new varieties originated through its use.

Grafting tools.—To insure success in all grafting operations, sharp tools are required in order that the cuts may be cleanly and neatly made.

A sturdy, straight-bladed knife that will hold a keen, smooth cutting edge is necessary for all types of grafting. If a large amount of cleft grafting is to be done a grafting chisel is desirable. A suitable one can be made from an old file. A heavy butcher's knife and a wood chisel or screw driver may be substituted for the grafting chisel. A piece of hard wood makes a suitable mallet for driving the chisel into the stump to be grafted. A hammer destroys the grafting chisel or knife. Hand pruners are possibly the most useful of any purchased tool and a good pruning saw would be next in value. Large pruners or lopping shears and a small plane are handy accessories when grafting.

Fig. 3.—(A) Grafting chisel with varying curvature; (B) hand shears; (C, D, E.) budding, grafting and pruning knives; (F) lopping shears; (G, H) saws; (I, J) brush-wax lanterns.

Strong string, and waxed tape or raffia are needed to bind the parts tightly in certain grafts. Wax is necessary for covering the wounds and preventing desiccation. Small brads with flat heads are necessary for certain grafts.

Selection and care of scions.—Scions are taken while dormant in fall or winter from growth of the past season and from a tree of the desired variety. Terminal, well-matured, new growth is the usual source of scion wood, preferably straight and a foot or more in length. Immature wood may lack stored food materials for starting growth. Taking scions from bearing trees has advantages with respect to assuring trueness-to-name of the variety, but wood from young trees may also be used.

Wood gathered in the early spring is frequently poorer than wood gathered in the fall before severe winter weather has set in.

Periods of thawing and freezing which usually occur in February and March are particularly injurious. With some apples, crabapples, pears, and plums, scions taken any time after the leaves fall until very early spring give satisfactory results. Apricots and other types of stone fruits give best results when cut in late winter or early spring (March) before any sign of growth is evident. Plums especially do not retain their buds well in long periods of storage.

The wood to be taken should be carefully selected, it must be well matured, firm not pithy, about $\frac{3}{8}$ " in diameter (about the size of a lead pencil) with well developed buds. When ready for use it should be dormant with plump but not swollen buds.

To keep scion wood in good condition if cut sometime previous to using, it must be stored under suitable moisture and temperature conditions. A cool root cellar or basement floor where the scions can be spread out on the earth and covered with about 2 inches of damp moss, sawdust or sand provides good storage. Clean sand is probably the safest material; a mixture of soil and weathered sawdust gives good results. Moss that is extremely acid in reaction will frequently damage scion wood, particularly if slightly wet. A thorough washing in running water will help to prevent this.

The covering material should be kept moist but not wet. A temperature of 30-40°F. is preferable, but it may vary considerably. If such storage is not available, burying the scions in a thin layer about 18 inches deep, on the north side of a building, where the soil is well drained but not dry, keeps them in good condition. A convenient practice is to place the scions lengthwise in a box of damp sand. The box is then buried about a foot or more deep on the north side of a building or hedge. Mulching the spot after the soil is frozen aids in retaining the frost in April. Scion wood should never be stored in bundles as the material in the centre will dry out or mold.

It is helpful to dip the individual scions quickly in a bath of parawax at a temperature of 140-160°F. before storing. This is seldom practiced, but with treasured wood it is desirable.

Scions may be shipped successfully when wrapped in dampened moss or peat, or when covered with wax, to prevent drying out.

Discard: (a) Scions which show injury from cold, as indicated by a browning of the tissues under the bark; (b) those which have dried out; (c) extreme tips formed the previous season, that are soft and immature with poorly developed buds; and (d) the bases of very vigorous shoots. Soaking the scions in water is likely to soften the bark and may result in decay, but washing the twigs before cutting into the scions may be advisable, to remove dirt adhering and save the sharp edge of the knife.

Cleft Grafting

Cleft grafting is one of the simplest methods of top-working fruit trees, particularly the apple.

When to cleft graft.—Cleft grafting is best done in the spring when the buds of the trees to be topworked are beginning to swell. If done too early the scions may dry out or be moved by wind or other factors. If done too late the sap flow may force out the scions, the bark may split too much, and the buds of the scions may not be dormant.

Preparing the scions.—Apple scion wood is cut into lengths usually carrying 3 strong buds after it is inserted. The scion is cut just slightly above (about $\frac{1}{4}$ inch) what is to be the top bud; avoid making the cut too close as the wood may dry back. The cut is sloped downward to the side opposite the top bud. Terminal buds that may be flower buds are discarded. A wedge 1-2 inches long is made downward below the lowest of the buds, with straight even strokes of a sharp knife. The wedge should have straight even sides but be slightly thicker on the outer side than on the side to

Fig. 4.—Cleft graft. (A) Branch cut to stub and chisel inserted for the cleft; (B) holding the cleft open; (C) properly cut scions; (D) scions inserted (note position of lower bud); (E) cross-section of stub with scions inserted; (F) all exposed cut surfaces waxed.

be placed towards the centre of the stock (not too much of a slant or the scion will tend to slip out of the graft). The purpose of the slant is to ensure contact between stock and scion at the cambium region and closing of the stock sufficiently to bring the outer edge in contact with the scion. Unless the sides of the scion taper evenly the point of contact may be only at its thickest portion, rather than throughout its length. The wedge of the scion should be made blunt at the lower end, so that the bark does not loosen from the scion when inserted in the cleft, does not "rock" and does not reduce the area of possible contact. Drawing the wedge to a thin point, through some minor irregularities in scion or stub, may make establishing contact difficult and the thinness of the wedge may expose the pith of the bevel surface and cut the woody cylinder surrounding it into two separate pieces that turn or crush, especially in small scions, under the compression of the stump.

It is advisable to cut the scion so that the lower bud will be on the outside near the end of the stock, because there is greater activity in the issues near the bud, than between the buds.

Where to cleft graft.—The scions may be placed in the trunk of young trees, or, more commonly, in the branches of larger trees. In the case of growths of small diameter, less than $\frac{3}{4}$ -inch, Budding, Whip Grafting or Side Grafting is likely to be more suitable than Cleft Grafting.

Branches, 1-2 inches in diameter, on which the grafts will develop a desirable framework should be selected for topworking. Every branch need not be topworked; 3-4 grafted branches on small trees and 6-8 on larger trees are usually sufficient to provide the foundation framework for the new variety. When several varieties are desired on the same tree, it may be desired to continue the original variety as well, so the number of grafts may be fewer than where the purpose is to topwork the entire tree. Often, with fast-growing small trees, a few branches should be left uncut until a year or two after grafting. The purpose of these "safety", "feeder", or "nurse" branches is to carry on the growth of the tree during the first season. This ensures hardening or early ripening of the wood, because, by reducing growth of shoots from the scions, more of the invigorating effect of cutting back goes into the branches instead of into the scions. Some shading to prevent sunscald, but not excessive shading by the branches is beneficial. The branches to be grafted should be within reasonable distance of the ground, otherwise the new head may be too high and the fruit be borne at the ends of long pole-like branches. Graft fairly close to the trunk, but not closer than 6 inches, rather than far out on the branches. It may be necessary to select secondary side branches, but avoid promoting narrow-angled, weak crotches. Under Alberta conditions, the lower the head the better the tree withstands the rigorous climate.

A reconstructed tree should be kept in mind. It is unwise to attempt to entirely topwork trees of large size in one year; take at

least two years, especially with trees of full bearing age, because of the severe pruning incident to cleft grafting. Work the centre and top of the tree the first season, otherwise the grafts may be shaded too much; work the side and lower portions the next and succeeding seasons. In cleft grafting it should be remembered that the earlier in the life of the tree the grafting is done, the smaller the amount of work necessary, the closer to the trunk the scions can be inserted, and the less the time required to complete the work.

Preparing the stock.—A place is selected for the graft where the wood is straight grained and free from knots or scars for several inches below the cut, to insure a straight even cut. The cut surface of the stub should be horizontal rather than vertical, otherwise the lower scion may grow up into and interfere with the upper. The stock should be sawn off carefully with a sharp, fine-toothed saw, without tearing the bark; loosening the bark at the side of the cut can be prevented by cutting or sawing through the bark entirely around the branch before sawing it off.

Inserting the scions.—An essential of successful grafting is that the cambium layers of scion and stock be brought into contact with each other. The cambium layer is that line or layer of cells found between the wood and the bark; it is commonly more greenish and slippery looking than the neighboring tissues, and during the growing season the bark peels there readily. As in the willow whistle, the layers that slip past each other are the ones to have touching in the graft. The bark of the stock is thicker, hence the cambium layer occurs farther in than in the case of the slender scion. Hence, with, for example, a 2-inch stub and a scion the thickness of a lead pencil, it is not proper to set the outer edges of the stock and scion flush; in this case the outer side of the scion should be slightly inside the side of the stock. It is unusual to be able to provide a perfect matching of the cambium layers for the entire length of the jointed parts, but the greater the extent of contact the surer and better will be the union; often, putting the scion in at an angle, with the top directed outwards, will insure contact and union enough to start the growth.

A grafting chisel or butcher knife and a mallet are used to make a split 2-3 inches deep in the stock. If a grafting chisel with a prong is not available, a wedge or peg to keep the cleft from closing and to facilitate inserting the scions without tearing the tissues can be made simply by whittling a piece of wood to the desired shape and size, or by the use of a screwdriver.

When the diameter of the stub is 1 inch or slightly less, one scion per stub is sufficient. With a diameter of 1-2 inches, two scions should be inserted, one at each side of the cleft. This is a "safety first" practice, but there is also the advantage that if the two scions grow the healing of the wound may be more rapid. In the case of larger branches, a second split may be made perpendicular to the first one, so that 4 scions may be inserted; however, grafting of the

large limbs is not recommended generally, because the time required for the wound to heal and the scion to attain the size of the supporting branch is too great.

When two scions are used, insert the larger one first, if the scions are of unequal size; if the smaller scion is inserted first it may drop out when the larger one is put in. As previously mentioned, the lower bud should appear at or just above the stub.

Waxing.—After inserting the scions release the spreading tension. The cleft in the stock then closes and clamps the scions in place. No tying is necessary. (See Grafting Waxes.)

A good plan is first to apply the warm wax (if a brush was used) to the top of the stock, letting it flow down into the cleft, forcing all the air out. After the top of the stock is thoroughly covered, apply wax to the split sides of the stock. Make sure that no bark cracks are left exposed where air may get in and dry out the scion. Next place a band of wax around the top of the stock, securely covering any bark that may have been roughened or torn with the saw. If, in the operation, the lower buds on the scions become covered with wax, no damage is usually done. A daub of wax on the top of each scion completes the waxing job. Thorough work in waxing is very important.

Under extreme drying conditions it may be advisable to wax the scions entirely after grafting, as well as for some distance along the stock below the union. Covering the graft with paper sacks may also be helpful in reducing drying out; as growth develops the sacks are at first torn open on the side to avoid too sudden exposure and then later are removed entirely.

Care must be taken in waxing not to displace the scions. Often only a slight pressure will move them enough to prevent a union taking place.

Pruning the grafts.—If two scions are used and both “take”, they should be left until the healing process is completed. Proper pruning of the scions keeps the scion which is to be removed from interfering with the growth of the one to be left, eliminates sharp-angled crotches and assures good unions. After the scions have made one year’s growth, each stock should be inspected and one scion selected, by reason of its growth or location, as the one that will become the permanent branch. Repress the scion that is eventually to be removed so that it may not interfere with the development of the other; this scion should be cut back to 6-8 inches leaving just enough growth to keep its side of the stock alive (remove it the second spring after grafting). Then only one of the scions remains, otherwise a bad fork will result. The scion selected to remain is also likely to need some pruning, especially if it has made a long growth. As the top bud of the new growth is most likely to produce the lateral branches the next season, it should be cut back in the spring enough to cause it to produce these lateral branches, at the desired distance above the point of grafting. If

more than one branch is produced by the scion, it is quite probable that one of them should be removed, as it is likely that they will be so situated as to later make a bad crotch. If not, then both may be left and headed back. The suckers that develop around the grafts should be removed.

Causes of failure in cleft grafting.—Some common causes of failure in the cleft graft are: (a) Uneven edges on the scion; (b) failure to secure proper cambial contact; (c) imperfect waxing; (d) lack of dormancy in the scions; (e) attempting to topwork species or varieties which are not congenial; (f) excessive shade; (g) drying conditions; (h) sunscald.

BARK GRAFTING AND INLAY GRAFTING

Bark grafting and inlay grafting are useful methods in topworking fruit trees, particularly in cases that do not conform well to the splitting of the stock, as is required in cleft grafting. The bark and inlay grafts have advantages over the cleft graft in the following respects: (a) Ease of securing successful union, especially in the stone fruits; (b) avoids splitting the stub; (c) favours more rapid healing; (d) not quite so much wood is exposed, hence is more easily kept from drying; and (e) permits the grafting of stubs somewhat too large for splitting. The bark graft or the inlay graft, however, is of doubtful value on stubs too large for cleft grafting as the scions may be blown out by winds. In fact, it is the factor of rather insecure union that is the chief objectionable feature to bark or inlay grafting.

For both bark and inlay grafting, the stock is cut as in the cleft graft, but a cleft is not made in the stub. The scions must be dormant (more detailed discussion on selecting and handling scions, which was given in an earlier section on Cleft Grafting, applies to the methods under discussion here).

Bark grafting is done in the spring, with dormant scions, when the bark of the stock slips readily. A slit is made in the bark of the stock for a distance of about $1\frac{1}{2}$ inches downward from the end of the stub. The corners of the top of the slit are separated and the bark is raised enough so that a scion can be inserted under it. The scions are prepared with a bevel about $1\frac{1}{2}$ inches long on only one side, or, and probably better, with also a short bevel cut on the opposite side. One or two scions, as in Cleft Grafting, are inserted in the stock. The scions are pushed beneath the bark until the lower bud is about even with the stock. One or two No. 20 gauge $\frac{3}{4}$ -inch nails, preferably with flat heads, are then driven into the scion to hold it firmly in place. All exposed cut surfaces must be well covered with wax (see Grafting Waxes).

For the inlay graft, the stock is cut to a stub as in the Bark Graft. Somewhat larger scions than in the Cleft Graft or Bark Graft are preferable. A rectangular-shaped piece of wood about $1\frac{1}{2}$ inches long is cut from one side of the scion; that is, first make

Fig. 5.—Bark graft and inlay graft. (A and C) Scions cut for inlay graft; (B) Scion placed and nailed; (D) slit for bark graft; (E) scion with two bevels; (F) scion with one bevel; (G) scions placed under bark; (H) exposed cut surfaces waxed; (I) channel for inlay graft, showing, at sides, bark peeled back at base; (J) a scion with two bevels and one with a shoulder; (K) scions placed and nailed.

an abrupt slanting cut to the centre or heart of the scion, about $1\frac{1}{2}$ inches from the lower end, and then make another cut from the lower end of the scion to the first cut, leaving a smooth surface with the edges practically parallel. The scion may be cut so that a bud will be present on the side opposite the shoulder or top of the rectangular cut; furthermore, when a strong, lower bud occurs somewhat below the top of the stub, the top may develop more quickly than if this bud is removed or not located there. The scion is then held temporarily in its prospective place at the side of the stub where it is to be inserted eventually. Its outline is then marked plainly on the bark of the stock with the point of a knife. Two clean parallel cuts, about $1\frac{1}{2}$ inches long, are made in the outlines in the stock to the depth of the cambium. The bark between the parallel cuts is lifted out; if the grafting is done on a warm day about the time the buds are starting into growth, or a little later, the small portion of the bark should slip readily leaving a clean surface of cambium cells exposed. If any of the inner bark adheres to the stock, it should be removed. The size and shape of the channel should be such that the cut surfaces of the scion will fit it closely. In preparing a scion the lower end of it may be cut off squarely or it may be cut with a short bevel which will slip under the bark at the bottom of the channel. When the scions are placed in the stock they are nailed or tacked there (as in the Bark Graft), and all exposed cut surfaces are waxed thoroughly. For treatment after the graft starts growth see the section on Cleft Grafting.

SIDE GRAFTING

The side graft gives best success on branches not over $\frac{3}{4}$ -inch thick. It is an easy method of grafting for use in topworking young

Fig. 6.—Side graft. (A) Scion prepared for side graft; (B) scion inserted; (C) side graft completed and waxed.

orchard trees up to 4 or 5 years of age. Side grafting, or veneer grafting, is used extensively in grafting under glass, as with ever-greens, but this phase of the subject is not discussed further here.

In making a side graft a long slanting cut is made downward nearly to the pith in the side of the branch or stock to be grafted. It is usually made 1 to 1¼ inches in length. By grasping the stock above the slanting cut and bending it slightly to one side the cut is sprung open, allowing a wedge-shaped scion to be pushed firmly into position. Care should be taken to match the bark of the scion and stock on at least one side. After the scion is in place and the stock released, the natural spring of the wood will grip the scion and hold it securely in position so that no tying is necessary. The stock may then be severed above the graft union, leaving just enough wood to serve as a spring to hold the scion in place. Exposed surfaces are thoroughly covered with wax.

OBLIQUE SIDE GRAFTING

This, a modification of the ordinary side-graft, has found favor because of the ease with which union is obtained and its suitability for working larger limbs than is practical with the ordinary side-graft. The scion is prepared as in Fig. 7-B, with 2 sloping cuts about one inch long made on two sides of the basal end of the scion, and in such a manner that the two cuts meet longitudinally on one side at an angle of 30° to 45°. A shallow oblique cleft is made in the side of the stock as in Fig. 7-A. The cleft should be slightly deeper than the width of the wedge at the base of the scion. The knife is then partly removed from the cleft to allow the toe of the

Fig. 7.—Oblique side graft. (A) Cutting the shallow oblique cleft in the stock; (B) prepared scions; (C) scion inserted.

scion to be inserted. When the scion has entered the cleft, the knife is removed and the scion wedge is then pushed right across the cleft (Fig. 7-C). The wound is then waxed to complete the operation.

WHIP-TONGUE GRAFTING AND ROOT GRAFTING

Whip grafting may be performed on (a) above ground parts of trees, or on (b) roots of trees. The stock should not be larger than $\frac{3}{4}$ -inch diameter at the place where the grafting is done. Outdoors, the purposes are: (a) to topwork young trees with trunks or branches of small diameter; (b) to re-work nursery trees where budding the previous year was unsuccessful; and (c) to "double-work" nursery trees, so that an intermediate piece occurs between the root and the top. Indoors, the whip method is used to propagate varieties, particularly apple varieties, on seedling roots. The procedure is simple and, because of the several uniting edges, forms a good union.

When to whip graft.—In whip grafting young trees outdoors, the work is done, with dormant scions, just as growth is about to start in the trees, or slightly later. During the winter the work is done indoors, partly accounting for the name "bench grafting".

Scion and stock.—Scions of the desired variety are usually made about 4 inches long from shoot growth gathered and stored in the fall or winter.

Outdoors the scions are inserted directly in the trunk of small trees (as in the nursery row), or in one- or two-year-old twigs of

Fig. 8.—Whip graft and root graft. (A) Slit made to one side of centre; (B) joining scion and stock; (C) the two parts must be flush on one side at least; (D) joined parts tied.

small orchard trees. In root grafting, the root-stock, which may be cut into pieces or be used whole, usually consists of 1- or 2-year old seedlings, and is dug in the fall and stored in a moist condition until midwinter when the grafting is done.

"Piece-root" grafts are made from portions of roots, and as large or slightly larger in diameter than the scion; preferably from seedlings with long, straight roots so that each root may furnish two or more pieces 4 inches long. "Whole-root" grafts are made from an entire root after digging; preferably from seedlings with branched or stubby roots. Somewhat larger trees may be obtained the first year from whole-root grafts owing to the larger root, than from piece-root grafts, but subsequently no appreciable difference may result. Trees topworked or propagated by budding are, of course, on whole roots.

An "own-rooted" tree is made from an unusually long scion (8 inches or so), the graft is set deeply enough in the soil that roots develop from the lower buds of the scion, and the seedling root removed after the tree is dug from the nursery row. "Own-rooted" trees can be successfully produced by grafting on the basal end of piece roots instead of the apical end. The graft is then grown for a year on its inverted root and the tree when planted has the stock in an inverted position. The stock nurses the scion but does not nourish it sufficiently. The restriction, if such is the case, stimulates root formation just above the union.

Making the cuts.—Uniform, sloping cuts are made, usually $1\frac{1}{2}$ to $1\frac{1}{2}$ inches long, diagonally from one side to the other, thus leaving about $\frac{3}{4}$ -inch cut surface on both scion and stock or root. The surface of the cuts should be flat not hollowed. The knife should have a thin stiff blade that will hold a keen edge. A tongue about $\frac{1}{2}$ -inch long is made in both scion and stock (or root), starting about one-third the distance from the sharp end ("toe") to the heel and extending back about one-half the length of the cut surface and parallel to the sides. In doing this, the cut end is held upright and the upper side braced with the forefinger. It is of some importance that the tongue be made by cutting; splitting leaves a rough surface which is not conducive to a good fit.

Joining scion and stock.—The tongue of the scion is slipped inside the tongue of the stock so that the scion is held firmly in place, as in Fig. 8-B. Make certain that the cambium (layer of tissue just under the bark) of one side of the scion is in contact with the cambium of the stock; this secures cambium contact on three surfaces. It is preferable, especially in root grafting, that scion and stock be of approximately the same size, but do not attempt to match both sides unless there is good cambium contact. It is essential in fitting the scion and stock together that the edges on at least one side be nearly flush. If the toe of either scion or stock projects much beyond the heel of the other, to avoid slow healing it should be cut off without disturbing the graft. Avoid the use of scions on stock of smaller

diameter. The lowest bud of the scion should be on the side where contact between the cambium of scion and stock is better.

Binding and waxing.—The stock and scion are then wrapped firmly together with moist raffia or waxed cord such as crochet cotton or common twine, or by means of grafting tape. No knot is required, the material being wrapped over a loose end at the start and pulled through a loop at the finish. Material that decays without constricting the graft is preferable. As soon as the grafts are growing well they must be examined to make certain that the wrapping is not girdling the stem. It is well to cut all wrapping at this time. This is best done by drawing a sharp knife up the back of the graft. Most wrapping material when waxed does not rot away quickly enough to prevent damage and must be cut.

With whip grafts made outdoors, the union and binding material should be covered thoroughly with grafting wax. Waxing is not always practiced in root grafting, but increases the percentage of takes.

Storing root grafts.—A few hours exposure may be injurious through drying out, especially in a warm room. However, if the work is done in a fairly cool room, where the air is slightly moist, the scions and stocks can be exposed an hour or two without injury; they may be kept covered with a wet sack. The grafts should be tied in bundles and, to keep them fresh, be placed in containers of slightly moistened sand, sawdust or sphagnum moss, the last two being lightest to handle. Store in a cool cellar, preferably at 40 to 45°F. Formation of callus or healing tissue along the edges of the

Fig. 9.—Root grafting. Left to right—Ordinary method (practically all roots arising from root stock); reversed stock (practically all roots from scion), a good method for obtaining scion on its own roots; ordinary long scion (note only few weak roots from long scion), not as good a method of obtaining roots on scion. (Photo courtesy W. L. Kerr, Experimental Station, Morden, Man.)

union is desirable and is the first noticeable sign of successful activity. Examine the grafts from time to time. If any mold appears unpack and expose to air until they dry somewhat, then repack in a slightly drier, clean material. If growth is starting from the buds before time for planting outdoors, store in a cooler place. Another good way to handle the grafts is to heel them in, singly, into narrow rows in boxes of moist peat; in this way every graft comes in contact with the medium.

Planting root grafts.—The grafts are planted outdoors in early spring (while dormant), about 6 inches apart, in nursery rows so that the union is below ground and only the upper bud shows above ground. Permit only one shoot to grow to form the tree. Cut off singly, into narrow rows in boxes of moist peat; in this way every shoot arises below the scion. After a season's growth in the nursery row, the trees may be sold as one-year-old whips, or be headed back to develop side branches during the second year.

Causes of failure in whip grafting.—Some common faults of beginners in attempting this graft are: (a) Failure to make the sloping cuts long enough; (b) uneven bevel slopes resulting from dull knife or failure to support the twig properly from the back when making the cut; (c) improper placing of the slit; (d) 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. Whip grafting will not be successful when there is a lack of congeniality between scion and stock varieties.

BRIDGE GRAFTING

Bridge grafting is practiced on apple trees for purposes such as the following: (a) To bridge over areas, particularly near the base of the trunk, where the cambium is dead; (b) to repair damage from gnawing by mice or rabbits or occasionally from bark peeling by sheep; (c) to repair damage from blight cankers on the trunk and from winter-killing; (d) to repair damage following mechanical injuries by orchard implements; (e) to graft a new root to an old tree; and (f) to preserve or prolong the life of trees injured by sunscald or collar rot.

There are many cases of real need for bridge grafting, as indicated above. There are cases, however, when advisability of bridge grafting is doubtful. If trees less than 3 years old are badly girdled the best plan may be to saw them off below the injured area and cleft graft, or dig them up and plant new trees. The need for bridge grafting can be eliminated by the use of wire screens for protection against rodents.

Methods of bridge grafting.—The two chief methods of bridge grafting are: (a) L-shaped method, best suited to trees with thin or only moderately thick bark; (b) inlay method, preferred for trees

Fig. 10.—Bridge graft. (A) L-shaped cut; (B) scions cut with two bevels; (C) scion inserted under bark; (D) cross-section of bridge graft in thick bark; (E) bark slits, single and double; (F) inlay bridge graft; (G) approach graft with sucker or seedling; (H) injured area cleaned for bridge grafting; (I) bridged and partially waxed (all exposed cut surfaces and scions should be waxed).

with thick bark, or where the scions are set in the roots. Since the ends of the scions are not cut very thin, they are less liable to damage from nailing than with some other methods. The inlay graft requires somewhat more skill than the L-shaped method and generally take more time.

When to bridge graft.—The best time for bridge grafting is in early spring following the injury, beginning when the buds are swelling and extending for 2 or 3 weeks thereafter. It should not be attempted until the bark slips well, otherwise raising of the bark is difficult, much of the inner bark may remain attached to the wood so as to interfere with the attainment of cambium contact and if scraped off the operation may injure the cambium cells on the wood and again prevent satisfactory union. Bridge grafting is occasionally successful when done in early summer, but careful selection of scion wood is necessary.

The scions. — Dormant, well-matured scions of the previous season's growth should be used. Since bridge grafting is not strictly a method of propagation, the variety from which the scions are taken is not of much consequence, although hardy congenial varieties are preferable. Scions with a curve at the base are useful for grafting on roots. The length and number of scions needed depends on the extent of the space to be bridged. The scions are made 3 to 4 inches longer than the space, or long enough that they more than span the area to be bridged, and permit a spring or bow on them. A spring or bow aids in contact, especially if there is a bevel cut on the scion, provides a certain amount of slack, and permits enlargement in diameter of the scion. It is much better to cut scions too long than too short. If scions are not long enough to span the dead or injured area they may be set diagonally, but this is not desirable; vertical placing of the scions is best. A scion for every 2 inches in the circumference of the injured part of the tree is usually sufficient.

Scions are prepared for the L-shaped method with bevelled cuts at both ends that are to face against the tree and a shorter bevel made opposite. Scions for the inlay method are prepared with larger, 3 to 4 inch, bevelled cuts that do not extend to the opposite side and so make thick cut ends relatively resistant to damage from nailing.

Preparing the surface of the tree.—Good condition of the wood surface of the tree at the points of contact with the scions is very important in bridge grafting.

Earth should not be rubbed over freshly made wounds or the cambium may be injured. Winding cloth about the injured spot may favour growth of molds, spoiling chances of regeneration. If the injury occurs in the winter the wounds should be protected, so far as possible, by a coat of paint (without turpentine) or grafting wax, to prevent drying. If wounds, made when the bark is slipping freely, are left absolutely alone, healing by regeneration of bark over the

wounded area (unless too large) may take place. Microscopical examination of sections through several bridge unions has indicated that a large part of the callus tissue through which connection was established came from this wood rather than from the scions. This fact has special application in bridging areas dead for some time as the tissue for some distance from the area originally killed may be alive but in such poor condition that grafts set in it may not take well.

It is often best to prepare the tree a day or two before bridge grafting. Remove all dead bark and, if the wound is old, remove any unhealthy live bark. Cover the exposed surface to within an inch of the edges with grafting wax to guard against invasion by wood-rotting fungi and to keep the sapwood from drying out. In case the injury extends to the roots, the earth must be removed from the base of the tree and the larger roots until sound bark is uncovered. Water conduction upward after girdling may continue for a longer time in an old tree than in a young tree. Downward flow of food material is one of the first effects assisted by bridge grafting.

Fig. 11.—Supporting poor crotches through grafting cross-shoots from other branches at appropriate points on the branches. In such a case one end of the graft is already attached, and the other may be inlaid on the branch in need of support. The essential feature is to bring the cambium tissues in contact and to hold them there until union has taken place. The branches may need to be kept from spreading by tying or wiring until the graft has united. Small soft shoots from opposite branches may be twisted together and tied to serve the same purpose. They will soon grow together.

Inserting the scions.—Preferably, make an L-shaped cut, with each arm about 1½-inches long, in the bark above the wound and an inverted L-shaped cut, of the same size, below the wound an inch or two from each edge. Raise the bark sufficiently in the angle of the L-cut to admit a scion, insert a scion, and drive brads through both bark and scion.

For the inlay method, place the end of a prepared scion according to its prospective position, mark the outline of the bark above and below the wound, remove pieces corresponding to scion size in the outlined areas, cleanly exposing the cambium tissue, and insert and nail the scion.

A spring or bow of the scion is secured by bending the scion over a wedge about an inch thick which is removed after the scions are nailed. The buds on the scions should be rubbed off so that the scions serve only as carriers. All exposed cut surfaces should be waxed, including the edges of the girdled area; a brush wax is preferable.

In case of extensive injury, young trees may be planted around the injured tree and their tops inserted above the wound; this is known as "approach grafting". Suckers coming up from around the base of an injured tree can be used as scions by grafting the top of the sucker directly into the trunk immediately above the wound.

RE-WORKING OF TREES—TOPWORKING AND FRAMEWORKING COMPARED

In topworking, the original top or head of the tree is removed more or less severely according to the size of the tree and the likes or dislikes of the grower. The branch system of framework of the tree is cut back to within about a foot of the main stem. In topworking only the end of these cut branches are worked with the new variety. It may be wise to take 2-3 years to complete the topworking in order to prevent too much of a setback in the root development and tree growth. Such a topworking system is comparatively simple and inexpensive, and has for many years been the popular method. It has, however, several disadvantages: (1) Removal of the branches severely checks root growth; (2) large wounds are formed which are slow to heal and require periodic attention or destructive diseases will enter; (3) the new growth is vigorous and very little fruit-producing wood will be formed for several years. Up to 10 years may elapse before normal fruiting is restored; (4) many of the first fruits borne are inferior in quality and size.

The term "Frameworking" may be applied to methods of reworking in which the complete framework of the tree is maintained and used for support of the scions and new growth. The framework is cleaned of spurs and small lateral branches. Reworking is carried out using whip-and-tongue grafting, side-grafting, or the multiple-bud system. Side-grafting is probably the most

satisfactory and yields quicker results than budding. Grafts are placed along the branch at quite regular intervals to provide an even distribution over the entire tree. The end of the branch is usually terminalized by the stub type of side-graft. Other grafts that may be used for frameworking are the Oblique-side graft and Rind grafts such as the inverted L Bark-graft and Awl-graft. Budding by the Plate or Dry-bud method has given fair results, the chief disadvantage being that more time is required for the trees to resume normal fruiting than where scions are used. The most satisfactory is probably the side-graft in its various forms.

Scions should be spaced 8-12 inches apart, the closer spacing usually brings the trees back to fruiting in shorter time, less new wood being required. About 80 scions would be required to furnish a well-developed ten to twelve year old tree. Care should be taken in placing the scions in good positions and out of the way of cultivating implements. The length of the scions when grafted is of great importance. If scions are short, containing only 2 or 3 buds, growth from these will be very vigorous and not likely to produce fruit for 2 or 3 years. By using longer scions containing 6-8 buds, vigorous growth is reduced or limited to the 2 or 3 buds near the upper end. The remaining buds will then form fruiting spurs on short growth which will produce fruiting spurs the following season. In this way the tree is brought back into fruiting much more quickly than by using short scions.

Scions should not be placed closer than about 1 foot from the crotch of the tree, to afford good development. The fitting of scions when making the grafts is important as ugly callus growth and weak unions may be the direct effect of poor workmanship.

Advantages of frameworking: (1) the branches of the tree are maintained and little damage done to root development; (2) removal of the large branches and formation of large wounds is avoided; (3) the health of the tree is not endangered as the small wounds are healed in one year; (4) all new growth goes into the formation of fruiting wood; (5) the frameworked tree returns quickly to profitable cropping. Usually 2-3 years is all that is required.

Its only disadvantage seems to be the greater cost of the operation as compared with topworking. The cost is not as much greater as it may be supposed. The grafts are quickly applied and if scion wood is plentiful cost is not prohibitive. The advantages, such as early return to fruiting far outweigh the disadvantages.

GRAFTING WAXES

A good grafting wax should have the following qualifications: (a) it should contain no material that will injure live tissue in the strength at which it is used; (b) it should not crack in cold weather; (c) it should not run in hot weather; (d) these properties should be semi-permanent; and (e) it should be economical.

Hand wax.—A hand wax or soft wax is a good general purpose wax. It requires no special equipment for its application since it

can be worked and spread by hand. It is not now as popular as it was formerly (for years it was the only wax used), because the cost per pound is higher, a larger quantity is used per graft, and the time required to use it is greater than with brush wax. It is made as follows:

Resin	4 pounds
Beeswax	2 pounds
Tallow	1 pound

These materials are melted together slowly without boiling; cooled somewhat, then poured into cold water. With the hands well greased with tallow pull the wax (as soon as it becomes cool enough to handle), as in making taffy, until it becomes straw coloured and uniform in texture. It may then be used immediately or be stored in rolls in oiled paper. In cold weather, $1\frac{1}{2}$ pints of linseed oil may be substituted for the tallow, to make a softer wax. A harder wax is made by increasing the amount of resin.

Standard brush wax.—This is popular for extensive operations. It is made as follows:

Resin	5 pounds
Beeswax	1 pound
Linseed oil	$\frac{1}{4}$ pound

Slowly melt the resin; add beeswax and melt; add linseed oil; take the mixture from the fire, and stir in the lampblack a little at a time to prevent boiling over. This wax is solid at ordinary temperatures. In the orchard the wax is kept melted by means of a small portable heater of simple construction.

The brush wax is applied in melted condition, often with a 1-inch paint brush, and hardens on the grafts after being applied. It flows into crevices, covers well, and can be applied in a thin coat. Although this wax must be melted to a consistency that will merely flow easily, it should not be heated any hotter as it may be injurious to tissues of the trees.

Lampblack ($\frac{1}{2}$ pound) has long been included in the formula for this wax. It was thought to provide toughness and pliability and that there was a beneficial effect from the black colour. Experience in Alberta, however, indicates that the use of lampblack is neither necessary nor desirable.

A lantern-like heater may be purchased, or the person who does the grafting may contrive a device which is easily carried and which will shelter a small flame and keep the wax liquid in a small container above it.

Modified brush wax—

Resin	10 ounces
Rendered sheep tallow	1 ounce
Beeswax	2 ounces
Boiled linseed oil	$2\frac{1}{2}$ ounces

Mix and melt, then pour into a pail of cold water. Grease hands, and pull until it is nearly white. When using, heat until it is easily applied with brush.

Alcoholic brush wax.—This wax is liquid at ordinary temperature. It is made as follows:

Pulverized resin	4 pounds
Tallow	$\frac{1}{4}$ pound
Wood alcohol	2 pounds

Melt the tallow; add the resin, and heat until entirely melted. Remove the mixture from the fire and stir until partially cool. Add the alcohol gradually, until the cooled mass is the consistency of paint. Keep the wax in a sealed container, such as a fruit jar, to prevent evaporation of the alcohol and hardening of the wax. It is applied cold, with a brush, and leaves a solid coating upon drying.

Paraffin brush wax.—Paraffin, used alone as a grafting wax, often cracks and breaks in cold weather; and, on warm days it is inclined to run, hence leaving the graft with insufficient protection. For a heavy coating, a number of light applications of plain paraffin may be necessary, especially if it is not applied while almost smoking hot.

High-melting-point paraffin has been increasingly used as an ingredient of brush waxes in recent years. Other ingredients are mixed with paraffin to give it added elasticity and sticking qualities.

Linseed oil	3 fluid ounces
Resin	1 pound
Paraffin	5 pounds

Melt the resin and linseed oil together and the paraffin separately. Then mix well. Pour into a shallow pan lined with oiled paper to cool in a cake 1 to 2 inches thick. This cake can be broken up and melted in a heater as wanted.

Another paraffin mixture used especially for coating scions and also suitable for covering grafts is: Paraffin, 4 parts; pick-up gum, a glue-like substance sold by commercial manufacturers largely for glueing packages, labels, etc., 1 part. The following formula has been suggested to substitute when the "glue-like substance" is not available: resin, 1 part; yellow beeswax (pure), 1 part; paraffin, 8 parts. Melt the first two on a low flame; when clear add the paraffin, and apply a little more heat until clear. Allow to solidify. Melt later as needed.

This almost transparent brush wax may be used in covering the entire scions, buds and all, as well as the cut surfaces of the stock, in grafting. It may be used for coating young nursery stock before setting out to keep it from drying out or for coating scions or nursery stock for long shipment. By use of this wax on scions with latent buds, that have not started growth, grafting may be done successfully even during the growing season. The covering of the entire scion should eliminate drying out even under adverse conditions; drying out of grafts is quite troublesome in Alberta.

Asphaltic emulsions.—Recently several asphaltic emulsions have appeared on the market under various trade names which make

good grafting waxes or wound dressings. Some believe that these preparations stimulate healing faster than other materials used for this purpose. These emulsions are applied cold with a brush. They must not be allowed to freeze before being used. Since they dry out quickly upon exposure to air, it is advisable to use a container holding just enough for immediate use. The reserve supply must be kept covered with water at all times to prevent drying out. If the emulsion is dry and heavy stir in a small amount of water.

Tape.—Adhesive tape or electrician's rubber tape may be used to cover the union instead of grafting wax. A special grade of tape known as nursery adhesive tape is made for this purpose. Some use both tape and wax to insure a tight covering. Strips of cloth soaked in melted grafting wax are very satisfactory.

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