Division of Agricultural Sciences
UNIVERSITY OF CALIFORNIA

PROPAGATION

of temperate-zone
fruit plants

C. J. HANSEN • H. T. HARTMANN

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The commercial fruit grower who wishes to apply the principles of propagation by budding and grafting in his orchards will find the necessary instructions in this circular. He will also find information on the propagation of fruit plants by cuttings, layering, suckers, and runners. The material should also be of interest to the nurseryman and to the home gardener.

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Fruits and nuts grown in California may be divided into two general groups: 1) temperate-zone fruits, chiefly deciduous, produced in both the northern and southern parts of the state; and 2) subtropical fruits which, while not limited to the southern area, are better suited to its warmer climate. This circular is concerned only with the propagation of temperate-zone fruits.

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PROPAGATION OF TEMPERATE-ZONE FRUIT PLANTS

C. J. HANSEN

H. T. HARTMANN

PLANTS MAY BE PROPAGATED in two general ways: by seeds and by vegetative propagation. As a rule, the use of seeds in the propagation of fruit varieties, although simple and economical, is not satisfactory; the seedlings produced are usually different from the parents, especially in size, shape, and quality of the fruit. In addition, the various seedlings are likely to differ from one another. This great variation, although undesirable to the plant propagator, is a valuable aid to the breeder who is trying to produce better plants. Fruit varieties that would come reasonably true from seed could be obtained by selection and breeding over several plant generations, but as each generation requires a number of years the time necessary would be prohibitive. The fruit-plant propagator must therefore use a vegetative method—that is, he must root some part of the parent plant, such as stem or root (cuttings, layering, and similar processes), or must place a part of one plant on another in such a way that it will grow (grafting and budding). In vegetative propagation a portion of the parent plant is simply growing in a different location, and therefore a plant so propagated will ordinarily be identical with the parent.

Placing a piece of branch—a section a

few inches long—in soil or in sand so that it will form roots and new branches is not difficult or expensive. This method—propagation by cuttings—is used for quince, fig, pomegranate, grape, olive, currant, gooseberry, and certain other fruits. Unfortunately, some of the principal tree fruits (for example, pears, apples, cherries, peaches, apricots, almonds, walnuts, and most plums) are so difficult to propagate by cuttings or similar methods that these procedures usually cannot be followed economically; such plants are generally propagated by growing seedlings and budding or grafting the desired variety upon them. The plants upon which fruit varieties are budded or grafted are called rootstocks. Seedlings are usually uniform enough for this purpose, but vegetatively-propagated plants are sometimes used to secure such benefits as disease resistance and uniform vigor.

Many additional varieties would be propagated on their own roots by cuttings or similar methods if this were possible or profitable. Sometimes, however, it would not be desirable. For example, certain rootstocks now available are more resistant to nematodes, diseases, or adverse soil conditions than are the varieties growing on their own roots.

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THE AUTHORS:

C. J. Hansen is Professor of Pomology and Pomologist in the Experiment Station, Davis.

H. T. Hartmann is Professor of Pomology and Pomologist in the Experiment Station, Davis.

ROOTSTOCKS FOR FRUIT PLANTS

SELECTING ROOTSTOCKS

Rootstocks in use are discussed below, and some information is given concerning the source of seed.

Almonds. The principal rootstocks for almond are almond and peach seedlings. Almond seed is sometimes obtained from bitter almond seedlings, but usually from commercial sweet almond varieties, such as the Texas. The choice between peach and almond rootstocks depends upon the experience of growers in the district where the trees will be planted, but if root-knot nematodes are present in the soil a nematode-resistant peach rootstock should be selected. (Additional information concerning peach rootstocks will be found in the section on peaches and nectarines.) Myrobalan plum (*Prunus cerasifera*) has been tried as a rootstock for almonds, but it is not commercially satisfactory.

Marianna 2624, a clonal selection of Marianna plum (*P. cerasifera* × *P. munsoniana* [?]), has been used to a limited extent as a rootstock for almonds in heavy, wet soils and in areas infected with oak root fungus (*Armillaria mellea*). It is propagated by means of hardwood cuttings. Ne Plus Ultra, Texas (Mission), Peerless, Jordanolo, and, in most cases, IXL are making satisfactory growth on this stock although considerable overgrowth usually occurs at the union. After 7 years growth in the orchard, trees of Ballico, Thompson and Merced on Marianna 2624 also seemed satisfactory. Nonpareil, Drake, Davey, Kapareil and Profuse, make unsatisfactory growth on Marianna 2624.

The ultimate size of almond varieties on plum roots is not known, but observations made during 21 years indicate that they will be relatively smaller than trees on almond or peach roots. Marianna 2624 is more resistant to oak root fungus than other rootstocks which may be used for

almond, but it should not be considered immune. Growing almond trees on Marianna 2624 is probably justified if the use of this rootstock is restricted to wet areas in orchards or to areas infected with oak root fungus.

Apples. In the past, rootstocks for apples have been grown to a great extent from "French crab" seed, imported mostly from France. The French crab trees are principally seedlings whose fruit is used for cider. In recent years, however, seed of domestic commercial apple varieties has been used in large quantities, and now accounts for a considerable part of the United States supply of rootstocks for apples. Nurseries growing most of the apple rootstocks for California, Oregon, and Washington obtain the seed chiefly from such varieties as Winesap, Rome Beauty, Delicious, McIntosh, and Yellow Newtown. Jonathan seed is also used, although some nurserymen think that the seedlings obtained are not completely satisfactory. Various agricultural experiment stations have tested the ability of the seed of many commercial varieties to germinate and to produce desirable seedlings. Most of the stations are satisfied with the seed of Rome Beauty, Delicious, Ben Davis, Whitney, and Winesap, but they do not recommend Baldwin, Rhode Island Greening, or Gravenstein seed.

If dwarf trees are desired, certain vegetatively-propagated rootstocks should be used. Two groups of such stocks are available: the EM (East Malling) series, and the MM (Malling-Merton) series; both were developed in England. Rootstocks in the MM series are resistant to wooly apple aphid. The most important stocks in these two groups are listed at the top of next page, classified into four levels of vigor as determined by the size of mature trees worked on such stocks. (Trees on seedling rootstocks are classed as "Standard" in vigor.)

Vigor

Standard (very vigorous)	EM XVI, EM XXV, MM 109
Semi-standard (vigorous)	EM II, MM 104, MM 111
Semi-dwarf	EM VII, MM 106
Dwarf	EM IX, EM 26

Rootstocks

Dwarf trees can also be produced by using a strong-growing seedling rootstock with an intermediate stem piece of a dwarfing variety, such as EM IX or EM VIII (Clark Dwarf).

Although much research has been conducted with these clonal rootstocks in other parts of the world, studies in California have been limited to small trial plantings of some growers. Further evaluations are necessary before definite recommendations on the use of these stocks in California can be made.

Apricots. The chief rootstocks for apricot are apricot and peach seedlings. Blenheim or Royal apricot seeds, easily obtained from drying yards and canneries, are commonly used. If root-knot nematodes are present, the grower may use apricot root or a root-knot nematode resistant peach rootstock (see section on peaches and nectarines). Apricot roots tolerate the root-lesion nematode (*Pratylenchus vulnus*) better than other rootstocks that may be used, but are more subject to gopher injury than peach roots are.

Plum roots, although not used extensively, should be chosen for heavy soils tending to be wet. Seedlings of myrobalan plum (*Prunus cerasifera*) and hardwood cuttings of Myrobalan 29C and Marianna 2624 (*P. cerasifera* × *P. munsoniana*[?]) are the plum rootstocks usually used. However, apricot trees on myrobalan seedling roots have not been wholly satisfactory; a small percentage has been broken at the graft union by heavy winds, and dieback has sometimes occurred. The trees on Marianna 2624 and Myrobalan 29C roots have made fair growth, but most of the trees growing on

these rootstocks are less than 24 years old. Marianna 2624 is more resistant to oak root fungus than are other rootstocks used for apricot, but it should not be considered immune. (Additional information on these plum rootstocks may be found in the section on plums and prunes.)

Cherries. Mazzard and mahaleb seedlings are common rootstocks for sweet cherries. Mahaleb gives the trees more resistance to buckskin disease, root-lesion nematode and drought, but it is more subject to root-knot nematode and gopher injury.

A sour cherry, the Stockton Morello, has occasionally been used for adapting sweet cherries to heavy, wet soils; although it is considered commercially satisfactory, Chapman and a few of the less important varieties sometimes do not do well on it. The most noticeable effect of this rootstock is a definite dwarfing of the sweet cherry top. It is propagated by means of softwood cuttings under mist, or by suckers. Seedlings of Stockton Morello should not be used, because of their variability.

Figs. No special rootstocks are used for the fig. The trees are propagated by means of hardwood cuttings, and are therefore on their own roots.

Grapes. If neither root-knot nematodes nor phylloxera are present in the soil, grape vines may be propagated by hardwood cuttings and thus be on their own roots. Where soil is infested with root-knot nematodes, the usual rootstock used is *Solonis* × *Othello* 1613. In very sandy soils of very low fertility where 1613 does not grow well the two *Vitis champini* rootstocks, Salt Creek and Dog Ridge, are

used. These stocks are extremely vigorous and should be used only in the poorest soils. Both are resistant to nematodes and have moderate resistance to phylloxera as well. Salt Creek is preferred to Dog Ridge, as the latter has extreme vigor and gives poor fruit set with varieties grafted on it.

If phylloxera is the principal problem, *V. rupestris* St. George is the recommended rootstock, especially on hillside and rocky soils where there is no irrigation. On irrigated lands and those having deep loamy texture, Aramon $\times$ *V. rupestris* Ganzin No. 1 (A. $\times$ R. #1) is recommended. These resistant rootstocks are all propagated by hardwood cuttings.

Olives. Because olive varieties can be propagated by cuttings the trees are often grown on their own roots; they are also budded or grafted on various rootstocks. In California, Mission, Ascolano and Manzanillo produce strong, fruitful trees on their own roots. Sevillano trees started from cuttings are somewhat smaller than grafted trees. Cuttings of Sevillano are difficult to root; those of Mission, Ascolano, and Manzanillo root readily. Seedlings of the Mission and Redding Picholine varieties are sometimes used as rootstocks for the major varieties, especially Sevillano, but the resulting trees are often variable in vigor and growth habit. Rooted cuttings of a strong-growing variety, such as Mission, are more suitable than seedlings as rootstocks and give more uniform trees.

Peaches and Nectarines. Peach and the nectarine are propagated almost entirely on peach seedlings grown from seed of commercial varieties, principally Lovell, and from seed of special rootstock selections such as Nemaguard, S-37, and Rancho Resistant. Apricot seedlings are occasionally used in sandy soils to resist root-knot nematode injury, but the union is not always successful.

Lovell seedlings are seriously injured by both species of root-knot nematodes known to cause trouble in California or-

chards, and should be used only where nematodes are not a problem. Seedlings of S-37 and Rancho Resistant are immune to one of the species of root-knot nematodes (*Meloidogyne incognita*) commonly found in California peach orchards, but are susceptible to the other (*M. javanica*). In some cases S-37 has not been as well anchored as other peach rootstocks. Nemaguard, a promising new rootstock, is immune or highly resistant to *M. incognita* and *M. javanica*.

Pears. The French pear, *Pyrus communis*, is the usual rootstock for pears. Most of the seed is from the Bartlett variety, the principal canning pear, but much Winter Nelis seed is also used. Rootstocks developed from Bartlett and Winter Nelis seed are referred to as either "domestic" or "French" seedlings. Trees on such seedlings apparently are resistant to pear decline.

Old Home (a blight-resistant variety) may be used for the framework branches, with French pear seedlings as the rootstock. Even a severe blight infection would not affect the resistant framework, on which a new top could later be built. Pears on own-rooted Old Home as a rootstock are vigorous, have the advantage of a blight-resistant root system, and are resistant to pear decline and black-end. Self-rooted Old Home rootstocks can be obtained by rooting hardwood cuttings, or by rooting leafy softwood cuttings under mist. They can also be obtained by grafting Old Home scions on rooted quince cuttings as a nurse root, with the graft union planted 2 to 4 inches below ground so that the Old Home stem will become rooted.

The Japanese pear, *Pyrus pyrifolia* (*P. serotina*) is an unsatisfactory rootstock because of black-end trouble and because of its susceptibility to pear decline. *Pyrus ussuriensis*, another Oriental species, is also susceptible to black-end and to pear decline. Only a slight amount of black-end has been found in orchards on *P. calleryana* roots, and the trees showing

the trouble are possibly replants and not on true *P. calleryana* roots. *P. calleryana* rootstocks are more resistant to rodents than are *P. communis* rootstocks, and more resistant to blight than are *P. communis* or quince. Where good pear psylla control has been practiced, trees on *P. calleryana* roots have shown resistance to pear decline.

If dwarf trees are desired, quince (*Cydonia oblonga*) roots are used. Because Bartlett variety does not make a good union directly with quince, it is necessary to double-work with a compatible interstock, such as Hardy (Beurre Hardy)—that is, to use a short piece of the compatible interstock stem between the quince root and the Bartlett top. The blight-resistant Old Home can also be used successfully as a compatible interstock between Bartlett and the quince root.

Trees worked on some quince clones as rootstocks are susceptible to pear decline.

Pecans. Seedlings grown from nuts taken either from seedling trees or from commercial pecan varieties are used as rootstocks.

Persimmons. Seedlings of three *Diospyros* species—*D. lotus*, *D. kaki*, and *D. virginiana*—can be used as rootstocks for varieties of the Oriental persimmon, *D. kaki*.

D. lotus seedlings are vigorous, drought-resistant, and produce a rather fibrous root which transplants easily. This stock is quite susceptible to crown gall, and does not tolerate poorly-drained soils. Hachiya variety does not produce well on *D. lotus* stock because of excessive fruit shedding. Scions of Fuyu variety are reported to make a poor union with this stock, although Fuyu top-worked on a *D. kaki* variety which has been established on *D. lotus* roots makes a satisfactory tree.

D. kaki is probably the best stock for general use, although the seedlings are difficult to transplant because they have a long taproot with few laterals. This

stock makes a good union with all varieties; the trees grow well and yield satisfactory commercial crops. Seeds for rootstock use may be obtained from any of the Oriental persimmon varieties that produce seeds.

D. virginiana seedlings are utilized as a rootstock in the southern part of the United States. Most Oriental persimmon varieties make a good union with this stock, which is tolerant of excess soil moisture and produces a desirable fibrous root. In California, Hachiya variety on this stock is dwarfed and yields poorly because of sparse bloom.

Plums and Prunes. The important rootstocks for plums and prunes are myrobalan plum (*Prunus cerasifera*) and peach seedlings, and Marianna 2624 (*P. cerasifera* × *P. munsoniana*[?]) and Myrobalan 29C, which are propagated by means of hardwood cuttings. Most varieties do well on these rootstocks.

Myrobalan 29C and Marianna 2624 are not injured by root-knot nematodes, but many of the myrobalan seedlings are susceptible. (Resistance to root-knot nematodes of the peach rootstocks is discussed in the section on peaches and nectarines.)

The roots of Marianna 2624 and Myrobalan 29C may be more shallow the first 3 or 4 years than are the roots of myrobalan plum seedlings and peach seedlings. Because of this, there is a tendency for young trees on Marianna 2624 and Myrobalan 29C roots to be blown over by heavy winds.

Plum or prune trees on peach roots are less susceptible to bacterial canker than are trees on plum roots. However, plum roots should be used in soil that is heavy and tends to be wet during part of the year. The use of peach roots for prunes in the interior valleys of California should generally be avoided, because it contributes in some years to excessively heavy crops and a resultant dieback condition of the trees.

Marianna 2624 is more resistant to oak

root fungus than are other rootstocks used for plums and prunes. Since some Marianna 2624 roots have been killed by oak root fungus, it will require a number of years to determine whether this rootstock has enough resistance to justify its continued use for this purpose.

Almond, which is occasionally used as a rootstock for plums and prunes, is satisfactory with many varieties provided soil conditions are suitable. However, it is probably best not to use this rootstock except in soils high in lime or boron. Trees on almond roots show some resistance to an excess of these substances.

Many varieties do well on apricot root, which is sometimes used in soils infested with root-knot nematodes, but Marianna 2624, Myrobalan 29C or a root-knot nematode resistant peach are now preferred.

Walnuts. Northern California black walnut (*Juglans hindsii*) seedlings have been the standard rootstock for Persian (English) (*J. regia*) walnut plantings in California for many years. They are vigorous enough in good valley soils suitable for walnut production. The seedlings are highly resistant to oak root fungus, but are not immune. They are susceptible to crown rot, root-lesion nematode (*Pratylenchus vulnus*), and black-line.

Paradox hybrid seedlings resulting from natural crosses of northern California black and Persian walnuts have been used increasingly during the past few years. They have usually shown greater vigor than northern California black walnut in foothill soils, in valley soils not of the best quality, and as replants. They will withstand fluctuating water table conditions better than northern California black walnut, are highly resistant to crown rot, and are partially resistant to root-lesion nematode. However, they are susceptible to black-line.

Persian walnut seedlings have been used in a few instances where crown rot and black-line are serious problems but where oak root fungus is not present.

STRATIFICATION OF ROOTSTOCK SEEDS

When removed from the plant, seeds of most deciduous fruit trees ordinarily will not germinate, even under ideal conditions of moisture and temperature. This is caused partially by the fact that the seed embryos are in a rest which must be broken by cold. In addition, the seeds of many plants are covered with a stony layer which must be softened before germination begins. The usual method of breaking the rest and softening the hard coat is to put the seed in a cool place between alternate layers of moist sand or other materials, such as vermiculite or a mixture of sand and peat moss. This treatment, called stratification, is begun in fall or winter, depending upon the kind of tree. The seeds remain in the stratifying medium until planted in the nursery. As a general rule, stratification should continue until the embryonic root is seen starting to push through the seed covering. The seeds should then be planted immediately. Some species do not require a stratification period for germination.

It is advisable, with most seeds, to soak them in water for about 24 hours before they are put into the stratification material.

The size of container (figs. 1 and 2) used for stratification depends upon the quantity of seed to be treated, and may vary from that of a polyethylene bag to a fairly large box or can. The seeds illustrated (fig. 1) are in layers because that is the easiest way to place them in the box. Slightly better results might be obtained by mixing the seeds and sand thoroughly so that each seed would be surrounded by a maximum amount of sand, but most nurserymen do not consider this step necessary. The stratifying medium must be kept moist; it is desirable to check the seeds at intervals during this period and add water if necessary, taking care to avoid excessive moisture.

Fig. 1. Side of box removed to show seeds of deciduous fruits being stratified in moist sand.

Airtight containers must not be used, as aeration is necessary during the stratification process. If necessary, cover the containers with wire screen for protection against birds or rodents.

If the winters are not too warm, seeds will receive enough cold in a shady, outdoor location. However, better germination may be expected with some seeds if they are stratified in cold storage at 33°

Fig. 2. Seeds being stratified in moist vermiculite in polyethylene bags.

to 40° F. The following are suggested stratification periods at 33° to 40° F:

30 days:	90 to 120 days:
Almond	Cherry
Apricot	Peach
60 to 90 days:	Plum
Apple	Walnut
Pear	

PLANTING ROOTSTOCK SEEDS

There are two methods of planting fruit tree seeds: (1) directly in the nursery row after the stratification period is complete, with the resulting seedlings budded the same year; or (2) thickly in a seedbed, with the seedlings moved to the nursery row the following winter or early spring. The second method produces trees with roots 1 year older than those produced by the first method. For either method, planting is usually done in February or early March.

Rootstock seeds planted directly in the nursery row after stratification are apricot, almond, peach, walnut, pecan, and sometimes myrobalan plum and mahaleb and mazzard cherry. (Because the tops of pecan seedlings grow rather slowly, it is usually necessary to delay budding or grafting until the second year.) Rows are usually 4 to 6 feet apart, with seeds about 4 inches apart in the row. If experience has shown that certain kinds of seed tend to germinate poorly, the grower may decide to plant them much closer than 4 inches and to thin later if necessary. The large walnut seeds are usually placed 4 to 5 inches deep; the medium-sized apri-

cot, almond, peach, and pecan, about 3 inches; and the smaller myrobalan plum about 1½ inches. To prevent drying out, seeds are usually planted deeper in light than in heavy soils, but this may not be necessary if irrigation water is always available. Occasionally, seeds have been planted directly in the nursery row in the fall without stratification. However, with this method it is difficult to maintain favorable moisture conditions in the field, rodents may destroy many seeds, and weeds growing in winter may be difficult to remove without disturbing the seeds.

Rootstock seeds grown one season in a seedbed and then transplanted to the nursery row are apple, pear, and sometimes myrobalan plum and mahaleb and mazzard cherry. The type of seedbed varies considerably, but commercial producers of seedling trees generally plant in rows far enough apart for convenient use of tractor-drawn cultivators. A stand of 10 to 15 seedlings per foot is usually needed to keep the trees from growing too large for satisfactory transplanting. If large numbers of seedlings are not required, the seed may be broadcast or planted in rows in beds of convenient size. Apple and pear seeds are planted about 1 inch deep, and cherry and myrobalan plum seeds about 1½ inches. Immediately after being transplanted to the nursery row, larger seedlings should be cut back to approximately 8 to 10 inches above ground. It is usually not necessary to prune those with tops less than 8 or 10 inches long. To expedite planting, lateral roots are usually cut back to stubs a few inches long.

VEGETATIVE METHODS OF PROPAGATION

The chief vegetative methods of propagation for deciduous fruits are budding, grafting, layering, and the use of cuttings, suckers, and runners. Often plants may be propagated by more than one of

these methods. The nurseryman knows how to secure the most plants for the least outlay in cost and materials, but a grower may sometimes use a method that would not be practical on a large scale.

BUDDING

Budding is the placing of a single detached bud upon a plant called the stock. This method is used by the nurseryman to propagate his plants and sometimes by the grower to change trees over to another variety. Some of the names given to methods of budding are based on the time of year in which the work is done. Spring budding is usually done in March or April, June budding in May or the first half of June, and late-summer or fall budding in July and August or a little later. Other names used are based on the method of cutting and inserting the bud, such as shield budding, patch budding, π budding, chip budding, and other, less important methods. In all these processes, success depends upon joining the cambiums of the stock and the bud. The cambium, or growing layer, is found between the wood and the bark.

Late-summer or fall budding in the nursery. Budding, although usually done in July and August, may be continued into September and October until the bark cannot be lifted. The budwood is collected from the current season's growth at the time the work is done, but may be stored a short while if kept cool and moist. The buds are either placed in trees grown from seeds planted in the spring of the same year, or (with apples, pears, and sometimes cherries and myrobalan plums) in trees lined out in the nursery row in the spring. In a few cases, vegetatively-propagated rootstocks are budded. About the time growth starts in the spring after budding, cut back the top of the rootstock to about $\frac{5}{8}$ inch above the bud (that is, just above the crosscut of the T, or top of the patch). Usually this cut slopes downward from the side where the bud is located. Remove all water sprouts appearing below the bud. The trees are dug in the winter after the buds have grown one season.

Trees thus produced will have either 2- or 3-year-old roots and 1 year-old tops.

They are, however, called 1-year-old, or yearling, trees; the age of the roots is not considered. In California, 2-year-old deciduous fruit trees (that is, trees with 2-year-old tops) are not usually offered for sale.

Late-summer or fall budding is the most important method used for deciduous fruit trees, although in recent years June budding has been used considerably to propagate some kinds of fruit trees.

June budding in the nursery. If advance orders and inquiries indicate that the supply of fall-budded trees will not meet the demand, and if the seedling trees have grown sufficiently in the three or four months since planting, June budding may be done in May or in the first half of June. Some nurseries have made it a regular practice to propagate a considerable number of trees by this method.

The usual procedure is to cut off the seedling top 2 to 5 inches above the bud 3 or 4 days after budding. Leave at least one leaf above the bud, and several below. It may be necessary to bud as much as 8 inches above ground in order to have a sufficient number of leaves below the bud. These rootstock leaves help to manufacture food for the tree until the leaves produced by the bud are large enough to take over this function. Make a cut back to the bud 10 to 16 days after budding. Thereafter, any shoots other than those from the bud should be shortened, and when the bud has grown into a shoot 6 to 8 inches high and has enough leaves of its own, remove all other leaves and shoots.

Budwood is collected from the current season's growth at the time of budding. As a rule, all wood is removed from the bud shield except a small core in the bud. The easiest way to do this is to make a long cut (fig. 3,A), and then, at the upper end, to make a cut through the bark only, rather than through both bark and wood. The shield may then be removed with a sliding motion, and the wood remains

Fig. 3. T, or shield, budding. **A**, bud stick with some buds removed (cuts should be started below buds); **B**, making crosscut at top of vertical slit; **C**, bud partly inserted; **D**, bud in place; **E**, bud tied with budding rubber. Moderate tension of the rubber gives best results.

attached to the bud stick. If the shield is pulled rather than slid from the bud stick, the small core of wood may become separated from the bud itself, and the result often is failure. Given ideal growing conditions, a medium-sized tree suitable for the orchard will be obtained by the time growth stops in the fall, and thus a year will be gained. Though the method described is relatively simple, heavy losses are likely to occur unless the work is carefully done.

Seedlings must grow rapidly in order to be large enough for budding in May or in the first half of June. Because the peach best meets this requirement, most June-budded trees offered for sale are on

this rootstock. Nurserymen list various varieties of June-budded peaches, nectarines, almonds, apricots, and plums.

June budding generally is feasible only in regions which have a long growing season.

Spring budding in the nursery. This is begun early in spring, as soon as the bark of the stock slips easily from the wood and allows the buds to be inserted, and should be completed before trees have made much new growth. This will usually be in March or April, depending on the kinds of trees and the season. As a rule, the bud sticks are collected in late winter, while dormant, and are stored in moist sphagnum moss or peat moss in a

cool place. They can be used for T, or shield, budding without further treatment.

For patch budding, however, the bud sticks must be transferred to a warm location and kept there until the bark will slip from the wood. By that time a few buds will have started to grow; these cannot be used, but others will be in good condition. Bud sticks for patch budding may also be cut directly from the tree at the time of budding, a practice thought by many to be the best. When this method is used, bud sticks on which part of the buds have started to grow are cut from the trees. Some buds will be in the right condition, that is, they will still be almost completely dormant, and yet the bark of the patches can be separated from the wood of the bud sticks—a requirement of patch budding.

About 2 weeks after budding, the tops of the stocks are cut off to force the buds into growth. The next winter, after the buds have grown one season, the trees are dug and sold. They are then essentially the same as the 1-year-old trees produced by late-summer or fall budding.

This method is usually less satisfactory than late-summer or fall budding, and should be used only for trees not successfully budded during the fall, or in some other special cases.

Selection of budwood. Buds for late-summer or fall budding and June budding should be taken from the current season's growth of the specified tree at time of budding, but for work in the spring dormant branches are usually selected and stored until needed. Although it is probably best to choose bud sticks having leaf buds (wood buds) only, many propagators use clusters containing both leaf and flower (fruit) buds. Do not use flower buds exclusively, because these blossom and die. Leaf buds are usually smaller and sharper pointed than flower buds.

In plums, apricots, peaches, and walnuts, a leaf bud usually occurs at each

node or joint, either alone or associated with one or more flower buds. A single flower bud is occasionally found on the bud sticks of these species, but not often enough to cause the propagator much concern.

Pear, apple, and almond bud sticks often have a number of single flower buds near the apical end. (In the pear and apple, these are really mixed buds, but usually respond the same as ordinary flower buds.) Since the apical end is customarily discarded because of its small size, the danger of using these undesirable buds is minimized.

The sweet cherry is most likely to cause trouble because its flower buds are located on the basal part of the shoots (fig. 4), a part which the propagator is likely to use if he does not know the position of the buds. The matter is further complicated by the fact that cherry flower buds are essentially the same size and shape as the leaf buds.

In all fruit tree species discussed above, more leaf buds will generally be found on the most vigorous shoots. The danger of using flower buds can be greatly reduced by avoiding the shorter, less vigorous type of growth.

Position of buds in nursery practice. Budding is usually done as near the ground as convenient, but northern California black walnut stock, which is resistant to oak root fungus, is often allowed to extend a foot or more above the surface of the ground. Other kinds of resistant rootstocks are commonly budded 4 to 5 inches above the soil surface.

Buds are usually inserted on the north side of the seedlings for protection against the sun during healing. In the hot interior valleys of California, however, where summer north winds are common, some propagators prefer to bud on the south side of the tree to prevent drying out of the bud, even though this practice may increase the possibility that the growing bud may be broken off by wind. There is another point in favor of the south side:

Fig. 4. Sweet-cherry shoots, showing basal position of flower buds. The lower few inches of cherry bud sticks should be discarded. Less vigorous shoots have more flower buds; more vigorous shoots have fewer flower buds. The possibility of using flower buds can be greatly reduced by avoiding shorter, less vigorous type of growth.

Fig. 5. Patch, or flute, budding. **A**, bud stick with patch cut, but not removed; **B**, patches with buds, removed from bud stick; **C**, patch of bark removed to receive bud; **D**, bud in place; **E**, wrapping completed. Notice that bud itself is not covered.

after the bud has started growth, the short section of seedling trunk on the side below the bud is less subject to sunburn than is the side opposite the bud. Therefore, less injury will occur if this more resistant side is placed on the south. Not only is sunburn in itself serious, but the damage caused by it is often followed by the entrance of flat-headed borers.

T, or shield, budding. This is the method most commonly used for deciduous fruits, except the walnut, pecan, and grape.

A bud with some bark and a thin layer of wood 1 to 1¼ inches long is sliced from the bud stick with a sharp knife and placed beneath the bark of the stock (fig. 3). The blade has the rounded point commonly found in budding knives. Leaves have been removed from the bud stick by severing leaf stems, or petioles, about ¼ inch from the buds. Beginners often use the leaf stem as a handle to aid in inserting the bud, but experts generally hold the bud between the knife blade and the thumb. If the bud cannot be easily pushed into place in the T cut, it

may be necessary to pull it into position with the point of the knife. This can be done with little injury to the bud by inserting the end of the knife a short distance into the shield just below the stub of the petiole. When doing this, hold the blade of the knife perpendicular to the length of the shield.

The details so far discussed refer particularly to late-summer or fall budding. They also apply to spring and June budding, except that no petioles are present on the bud sticks used for spring budding because the sticks are collected in winter when leaves are not on the trees. In June budding, the wood is usually removed from the buds by some method such as the one described on page 12.

The T cut in the stock that will receive the bud is generally upright, although sometimes an inverted T is used. Most budders make the vertical cut of the T first, then with a single movement they make the crosscut and throw open the bark to receive the bud. Some, however, make the vertical slit last. By whatever method the T is cut, the bud is inserted

Fig. 6. Patch, or flute, budding tools. Left, type with four blades; center, budding tool with two parallel blades, suitable for a limited amount of work; right, two-bladed budding knife of the type commonly used by commercial budders.

far enough so that its top does not project above the crosscut of the T. The vertical slit should not be longer than necessary to accommodate the bud. If it is too long, the lower part of the shield may not be adequately covered. Although raffia and string have been used to tie the bud, such materials have been practically replaced by budding rubbers, which need not be cut to avoid constricting the stem. These will stretch as the tree grows, and after a few weeks they rot and fall off. Raffia or string, if used, should be cut in 10 days to 2 weeks. Wrapping should begin at the top of the T and proceed downward so that the bud will not be forced upward. The budding rubber is held in place by inserting the end back under the last turn. The bud itself is not covered by the wrapping material (fig. 3).

With some plants, better results have been reported when the wood has been

removed from the buds, but with deciduous fruits this is done only when June budding is practiced and when (in a few instances) T budding is used for walnuts and persimmons.

In order to force the bud into growth, it is necessary to cut back the top of the rootstock to about $\frac{5}{8}$ inch above the bud (that is, just above the crosscut of the T). The time to do this depends on whether the trees are being fall, June, or spring budded.

Patch, or flute, budding. This is commonly used in propagating thick-barked trees, such as walnut and pecan. A square or rectangular patch of bark is removed from the seedling and replaced with a similar one that includes the bud desired. This latter patch is slid rather than pulled from the bud stick so that the small core of wood in the bud itself will be retained. Figure 5 illustrates the steps taken. Be-

Fig. 7. Patch, or flute, budding stock branches which have bark thicker than that of the budwood. Left, patch removed and stock bark pared down; right, bud in place and ready for wrapping.

cause a good fit at the top and bottom of the patch is necessary, most tools used have two parallel blades 1 to $1\frac{3}{8}$ inches apart, for the horizontal cuts. The vertical cuts are made with an ordinary budding knife. The tool in figure 6, center, may easily be made from a small piece of wood, two safety-razor blades, two bolts, and two metal strips, one on the outside of each blade to hold it in place. If considerable work is to be done, a stronger knife (fig. 6, right), consisting of two budding-knife blades rigidly attached to each other, is preferable. This is the type usually used by commercial budders. Some tools have vertical knives in addition (fig. 6, left), but this type of budding knife has not been entirely satisfactory. If the bark of the stock is thicker than that of the budwood, the stock bark must be pared down as shown in figure 7, so that the patch can be tied firmly in place. The usual wrapping material is waxed cloth or budding tape. String and rubber bands are not recommended because they are less effective in preventing drying out. Waxed cloth, budding tape, or string should usually be cut in 2 or 3

weeks. If the stock is making very vigorous growth, however, it may be necessary to cut the wrapping material in about 10 days to prevent constriction. In cutting these materials it is best to make the cut on the side opposite the bud.

Because the leaf bases of trees commonly T-budded are not large, they do not interfere with wrapping the bud. Walnut and pecan leaf bases, on the other hand, are rather large and make wrapping difficult. Most propagators cut the leaves off the budwood, except for short stubs, 2 or 3 weeks before budding. Leaves on the terminal ends of bud sticks should be left uncut. By the time the bud sticks are removed from the tree the short stub of the leaf stem, or petiole has dropped off or may be easily removed.

Ring, or annular, budding is the same as patch budding except that a complete ring of bark is removed around the stem. This method is slower and has no particular advantage.

In order to force the bud into growth, it is necessary to cut back the top of the rootstock to about $\frac{5}{8}$ inch above the bud (that is, just above the top of the patch).

Fig. 8. Steps in chip budding grapes. Left to right: bud removed from bud stick; notch made in stock to receive bud; bud in place; bud tied, ready to be covered with soil. Chip budding is seldom used for deciduous fruits other than grapes.

The time to do this depends on whether the trees are being fall or spring budded.

Many nurserymen whip-graft (see p. 22) seedlings whose buds fail to unite. This is done in the winter after the budding.

Hinge, $\perp$, or modified H, budding.

This method is sometimes used in place of the patch bud when the bark of the stock is considerably thicker than that of the budwood. It eliminates the need for paring down the bark of the stock to hold the patch firmly in place.

The cut in the stock is made in the form of an $\perp$ (like an H on its side). A patch containing a bud cut as for patch budding is inserted under the flaps of the $\perp$. Wrapping is done as in patch budding. This method is reasonably satisfactory, but unless care is taken the patch may buckle slightly and not touch the stock under the bud.

Chip budding. In budding small grapevines, more consistent results have been obtained with chip budding (fig. 8) than with other common methods. Root-stock rootings, resistant to phylloxera or root-knot nematode are planted in the vineyard in the spring, and are budded the following August in nonirrigated vine-

yards and in September in irrigated ones. For good results, buds must be taken from mature canes in which bark color has changed to brown. The stock must be growing actively at the time of budding.

Figure 8 shows how a chip is removed from the stock and replaced with a chip of similar size and shape carrying a bud of the desired variety. To facilitate the removal of the bud from the bud stick, the first cut is made at the base of the chip deep into the stick, at an angle of about 45 degrees. Buds are placed just above ground level and tied with budding-rubber strips. They are covered immediately with about 6 inches of pulverized soil. The rubber must be cut and removed the following spring but only after the bud on the chip has grown out at least $\frac{3}{4}$ inch. At that time the top of the vine is cut off about $\frac{1}{2}$ inch above the bud union. Chip budding is seldom used for deciduous fruits other than grapes.

Top budding. Budding is done mostly by nurserymen to propagate their plants, but also by the fruit grower who wishes to change his trees over to another variety. The only differences between orchard procedure and that followed in nursery work are that the buds are in-

TABLE 1— Grafting Affinities of Some Common Deciduous Fruit Tree Species

Scion	Stock											
	Almond	Apple	Apricot	Mahaleb cherry	Mazzard cherry	Stockton Morello cherry	Peach	Pear	Myro- blan plum	Quince	English walnut	Northern California black walnut
Almond.....	SC	—	US	—	—	—	SC	—	US	—	—	—
Apple.....	—	SC	—	—	—	—	—	US	—	US	—	—
Apricot.....	US	—	SC	—	—	—	SC	—	SC	—	—	—
Cherry.....	—	—	—	SC	SC	S*	—	—	—	—	—	—
Peach and nectarine.....	PS	—	PS	—	—	—	SC	—	US	—	—	—
Pear.....	—	US	—	—	—	—	—	SC	—	SC†	—	—
Plum (Japanese and Euro- pean)†.....	S*	—	S*	—	—	—	SC*	—	SC	—	—	—
Quince.....	—	US	—	—	—	—	—	US	—	SC	—	—
English walnut.....	—	—	—	—	—	—	—	—	—	—	SC	SC

— indicates grafts that will not grow, or where growth is very weak and short-lived.

S indicates satisfactory grafting affinity; SC indicates satisfactory and most commonly used in California.

US indicates grafts that will grow for a while, but are unsatisfactory.

PS indicates grafts that are partially satisfactory.

* A few varieties in these combinations do not make satisfactory unions.

† Some pear varieties, such as the Bartlett, do not make good unions with quince, although others, such as the Hardy, do. They are therefore double-worked with Hardy or with some other compatible variety.

‡ In general, many European and Japanese plums may be grafted on European plums. Although many Japanese varieties do well on other Japanese varieties, European varieties are not successful on Japanese. Peaches, almonds, and apricots may sometimes be grafted on Japanese and European plums with fair success, but as a rule they either fail to grow or grow unsatisfactorily. If plums are to be grafted, consult one of the following references:

Heppner, M. J., and R. D. McCallum. Grafting affinities with special reference to plums. California Agr. Exp. Sta. Bul. 438:1-20. 1927.

Allen, F. W. Plum growing in California. California Agr. Ext. Cir. 34:1-66. 1929.

Day, Leonard H. Rootstocks for stone fruits. California Agr. Exp. Sta. Bul. 736:1-76. 1953.

Although these publications are out of print, copies are usually available for reference in public libraries.

serted higher in the tree, usually in the branches, and late-summer or fall budding is often done earlier. This earlier budding in the orchard is generally necessary because the trees cannot be kept growing so vigorously in the field as in the nursery, and it is impossible to lift the bark later in the season. Late June, as soon as well-matured budwood is available or July, is an excellent time to top-bud. If budding is done at that time, the top of the branch above the bud is not cut back until about the time growth starts

in the spring after the budding. Spring budding in March or April, although sometimes practiced, is usually less satisfactory.

Fairly large limbs may be budded, but with difficulty. If old trees are to be budded, they are usually cut back the winter before in order to force out new branches in which to place the buds. It is usually best to top-bud only young trees and to use some method of grafting—such as cleft, bark, or saw-kerf—for the larger branches in older trees.

GRAFTING

Grafting differs from budding (which is itself a type of grafting) only in that the scion (a short section of a shoot), instead of a single bud, is placed upon the stock. The different kinds of grafting are classified according to the part of the plant upon which the scion is placed and the actual method of putting the scion on the stock. Based on the position of the graft, there are five classes of grafting: root grafting; crown grafting; top grafting; bridge grafting; and inarching.

As a rule, closely related plants may be grafted one upon the other. Since there are many exceptions, however, table 1 has been included to show the combinations possible among the common deciduous fruit tree species.

Selection and Storage of Scion Wood

Scion wood is collected while dormant during the winter. In some cases it may be used immediately, but with certain methods it may be necessary to store the scions in a cool place in moist sphagnum moss or peat moss. The scions and the moist material may be placed in a box, wrapped in waterproof paper, or enclosed in a polyethylene plastic bag. It is important not to have the moss too wet—it should release only a small amount of water when squeezed. The best place to store the scion wood is in a refrigerator at

a temperature a little above freezing. However, a cool cellar or similar location is satisfactory if the storage period is not too long.

Shoots that are soft, with a large pith (the central, soft portion of the stem, surrounded by wood), should be discarded in favor of a more solid type of growth. Often the apical third, or even more, of each shoot must be discarded in order to eliminate undesirable scion wood. The precautions just discussed apply particularly to the English, or Persian, walnut. The danger of using flower buds (see budwood selection, p. 14) is much less in grafting than in budding. Since two or three buds should be present on a scion used in grafting, the likelihood of having at least one leaf bud is greater than in budding, where only one bud (or cluster of buds) is present. Besides, flower buds can be distinguished from leaf buds more easily at grafting time than at budding. Care should be taken to avoid having too many flower buds on scion wood, especially in cherry.

Most scion wood consists of shoots that have grown for one season. Usually, such 1-year-old branches are of a size suitable for grafting and have enough strong leaf buds. Older wood is sometimes employed if satisfactory buds are present; in the fig, 2-year-old scion wood is preferable.

When using the scion wood, the de-

sired grafting cut should be made starting at the base (after discarding the first inch), then the scions should be cut to proper lengths. This will facilitate holding the scion while the grafting cut is made, and will reduce the amount of wood wasted.

Root Grafting

This method consists of grafting a scion 3 to 6 inches long on a whole root or a portion of a root. California nurserymen bud instead of root graft, but the method is used by some nurserymen in the Midwest mainly for the propagation of apples. Either piece-root or whole-root grafts may be used for apples, but whole-root grafts are best for pears. Roots are dug in the fall, and grafting is done indoors during the winter. Since the work is carried on at a table or bench, the term "bench grafting" is sometimes used. The whip, or tongue, graft is commonly used for root grafting.

Whip, or tongue, grafting. At the base of the scion and the top of the stock, sloping cuts $1\frac{1}{2}$ to $2\frac{1}{2}$ inches long are made (fig. 9). The cuts should be adjusted to the size of the branches or roots being grafted; they should be longest on the pieces with the largest diameters. On each of these cut surfaces, starting about one third of the distance from the tip, a reverse cut $\frac{1}{2}$ to $\frac{7}{8}$ inch deep is made. This second cut should not be with the grain of the wood, but should tend to parallel the first cut. However, if the first cut is long enough, a reasonably satisfactory graft may be made even though the second cut is made with the grain. The two pieces are then fitted together and wrapped. Nurseryman's tape, plastic tape, or a light twine, dipped in melted grafting wax, may be used as wrapping material. The various wrapping materials used for whip grafting have their advantages and disadvantages, but nurserymen's tape is considered best under most conditions. At this point, apple root grafts are ready to plant, but pear root grafts

Fig. 9. Whip, or tongue, grafting. Left to right: stock and scion prepared; parts fitted together; graft wrapped with waxed light twine. For top working, where graft union is aboveground, thorough waxing is necessary. If stock and scion are not exactly the same size, the cambiums cannot be matched on both sides. They are therefore fitted together in such a way that the cambiums of stock and scion come together on one side.

are usually waxed over except where tape has been used. If the work is done in winter when the nursery is too wet to cultivate, the grafts must be stored until early spring in cool, moist sand, moss, or some similar material. Stored grafts will callus, and unless they are carefully handled, the partial union of the stock and scion may be destroyed. The grafts are usually planted deep enough so that only the upper bud is aboveground.

When the whip graft is used in top-working young trees, all cut surfaces should be covered with wax, except that with tape the wax is necessary only on the tip of the scion. Tape and the stronger

Fig. 10. Modified whip, or tongue, grafting for use with stocks that are considerably larger than the scions. Left and center, two views of a prepared graft; right, graft wrapped with nurseryman's tape, and cut surfaces waxed. Cambiums must be matched on one side, but experience has shown that usually only partial matching is possible on the other.

types of string, when used for whip grafting aboveground, must be cut after the parts have united, to prevent constriction.

Grapes are sometimes whip grafted to phylloxera-resistant or root-knot nematode-resistant rootstocks; but disbudded cuttings of the rootstock variety, about 12 inches long, are commonly used instead of root pieces.

Crown Grafting

In this method the graft is made at or near the crown of the plant. California nurserymen often use this method in propagating English walnuts. The whip graft (fig. 9), the method used in this type of walnut propagation, may have to be slightly modified if the stock is considerably larger than the scion. The surface of the sloping cut on a large stock will be longer than that of one made at the same

angle on a small scion. To eliminate this difficulty, the stock may be cut off squarely (fig. 10) and the sloping cut made just deep enough to expose a surface equal in length to the cut surface of the scion. When nurseryman's tape is used (fig. 10), wax is applied to the top of the stock and the top of the scion. If the tape shows a tendency to come loose a little wax may be applied to the free end.

If the trees are to be planted where oak root fungus is present, the graft union should be a foot or more above the soil surface, and the resistant northern California black walnut should be used as a stock. Such grafts are highly susceptible to sunburn. A satisfactory procedure for preventing this type of injury is to whitewash the entire aboveground part of the tree, including the scion. (Persimmons are also often crown grafted in much the same manner as walnuts.)

Crown grafting is also practiced in changing from one grape variety to another. In this work either the cleft graft or the notch graft (see top grafting, below) is used. The graft is made 1 to 6 inches below ground on vines on their own roots, and 2 to 6 inches aboveground on resistant rootstocks. The entire graft is covered with a large mound of moist, loose soil. It is not waxed.

Late winter or early spring is the usual time to crown graft.

Top Grafting

This is the usual method of changing from one variety of fruit to another. This and top budding (p. 19) are generally classed together as top-working. In top grafting, scions should be placed in branches of not more than 3 or 4 inches diameter. It is almost impossible to exclude wood-rotting fungi from very large cuts. If good-sized trees must be top-worked, usually the grafts are placed high where the branches are reasonably small. This procedure will be more expensive because it requires more grafts. In addi-

Fig. 11. Four-year-old top-grafted cherry tree, with stock and scions whitewashed to help prevent sunburn.

tion, it leaves more branches that must be kept free of fruiting wood of the original variety. On the other hand, trees grafted high in reasonably small branches will usually bear sooner than trees grafted close to the ground, and the income from this fruit will more than offset the original expense.

A limited number of spurs and small branches should be left on the top-worked trees below the grafts or buds to help protect the tree from sunburn and also to manufacture some food for roots until the grafts are large enough to take over that function. These branches and the water sprouts that appear later must be cut back to keep them reasonably small. Later, all such growths should be completely removed.

Figure 11 shows a typical top-grafted tree.

Sometimes only a part of the branches is grafted at first, and the remaining ones grafted the next year. This procedure is somewhat more expensive but no better than cutting off the entire top at the time of grafting, and it is not recommended for deciduous fruits in California. In evergreen trees, such as citrus and olives, a few branches are often left as nurse limbs until the new tops have become well established, at which time the branches are removed.

The proper season to top-graft trees depends on the method used. Bark grafting can be done only in the early spring after the bark of the stock has begun to slip. Cleft, saw-kerf, whip, and side grafting may be done over a rather long period beginning in January. Even earlier grafting has been done, but is usually not advisable because the scions may dry out.

Cleft grafting. This method of top-working trees has probably been used more than all others combined. The grafting may be done at any time during the dormant season, and may be continued after the stock has begun to grow if the scions are kept dormant. If the work is done very early in winter there is more opportunity for the scions to dry out, especially if the waxing has not been thorough. On the other hand, most propagators believe that more scions will grow if the grafts are completed before the trees have made much growth; consequently, most cleft grafting is done in January, February, and March.

In cleft grafting, after the top of the tree has been sawed off, the stock branches are split down the center (fig. 12). The splitting tool may be either a special one with a concave blade designed to cut the bark first and so prevent peeling, or an old kitchen knife. Whatever type of knife is used, it is driven in $1\frac{1}{2}$ to 2 inches. It is then removed and a narrow wedge is driven

Fig. 12. Cleft grafting. Left, stock split with grafting tool; right, cleft is open, ready for scions.

into the center of the cleft or the split, to hold it open while the scions are inserted. The wedge is often a part of the splitting tool (fig. 12). Some grafters trim the edges of the cleft with a knife, but this procedure is advisable only with difficult species or with unusually rough clefts.

Scions 3 or 4 inches long and containing not over two or three buds (fig. 13) are usually selected from 1-year wood of the variety desired. Details concerning the type of scion wood to be used may be found on page 21. Scions are cut wedge-shaped, with the outer edge slightly thicker than the inner. This unequal cutting insures contact between the cambium of the stock and the cambium on the outer part of the scion. Figure 14 (center), showing part of the stock cut away, illustrates the proper position of the scions. As this figure indicates, the cambium on the inner side of the scion does not touch the cambium of the stock. If, therefore, the thick side of

Fig. 13. Cleft grafting: two views of a prepared scion. These are cut wedge-shaped at the lower end (right), with the outer edge slightly thicker than the inner to insure contact of cambiums. The lowest bud should be on outside edge of the scion and should be located just above top of the wedge-shaped cut.

Fig. 14. Cleft grafting. Left, scions in place; center, part of stock removed to show how cambium of stock is brought into contact with cambium of scion. Scions are slanted outward slightly to make sure that cambiums touch in at least one place. Right, completed graft covered with wax.

the scion were accidentally placed to the inside of the stock, it would hold the cleft open slightly and prevent contact of the cambiums. Scions properly placed in thick-barked branches are not flush with the surface of the stock branch, but are set in a distance almost equal to the thickness of the stock bark.

Figure 14 (left) shows wedge removed and the two scions in place. All cut surfaces, including the tops of the scions, are then waxed over. More than two scions may be placed in one stock branch by making more than one cleft. If more than two scions seem desirable, the bark graft or the saw-kerf graft is preferred.

Bark grafting. Since the stock is not split in this method, decay organisms cannot enter so easily as in cleft grafting. On the other hand, bark grafting is disadvantageous in that it may be done only in the early spring after the bark

has begun to slip. By that time the buds are usually opening on the 1-year wood that is to be used for scions. Usually, therefore, the scion wood must be gathered while still dormant and stored in a cool place in moist sphagnum moss or peat moss. It will keep best in cold storage at temperatures a little above freezing, although a cool cellar or similar location is satisfactory if the storage period is not too long. Additional details may be found on page 21.

Storage of scion wood may be unnecessary in some instances where late-leaving varieties are grafted on early-leaving varieties, the scions being taken directly from the tree and used immediately. In addition, in the olive, scion wood may be taken directly from the tree at the time of grafting—March and April in California.

Various modifications of bark grafting have been described, but only three of

Fig. 15. Bark grafting. Three views of a prepared scion. Left, side view; center, side of scion that rests against the wood of stock; right, opposite side of center view.

the best will be considered in detail. If the work is carefully done, all three will give satisfactory results, but some are easier than others.

The bark-grafting method illustrated in figures 15 and 16 will be considered first because it is the type usually described. Although still important, it is gradually being replaced by the other two methods. The scions are usually cut as shown in figure 15, although slight modifications may be made, especially in the size of the shoulder. When nails are used to hold scions in place, the only function of the shoulder is to reduce the thickness so that the stock bark will not be pushed out too far when scions are inserted. When waxed cloth, tape, or string is used to hold scions, the shoulder may help to keep them in position. Small scions may be made with little or no shoulder, whereas large ones will require a larger shoulder than illustrated. Care should be taken not to make the scions too thin, or they may be broken off after growth begins. Although a perfectly square shoulder may be made with a fine-toothed saw, the results have been no better than when the scions are cut as in figure 15. The slit in the bark of the stock (fig. 16) should be just long enough so that the scion can be pushed in place without splitting the bark. The scion is placed in the center of the slit. As a rule, one nail is then driven through it, and one through the bark of the stock on each side of the scion. Usually an additional nail is put through the lower part of the scion. The proper size of the nails depends on the size of the scion wood, but for most deciduous fruits, except walnut, No. 20 flat-headed wire nails $\frac{5}{8}$ or $\frac{3}{4}$ inch long are satisfactory. The large walnut scions usually require No. 19 flat-headed wire nails 1 inch long. As soon as possible after the grafting is completed, all cut surfaces, including the tops of the scions, are waxed over.

Nails are recommended in bark grafting, but if desired the scions can be held

Fig. 16. Bark grafting. Left, slit made in bark of stock; center, scions nailed in place; right, completed graft covered with wax. The use of nails is recommended for bark grafting. If nails are not used, waxed cloth, tape, or string should be tightly wrapped around the stock to hold the scions in place.

Fig. 17. Modified bark grafting. **A**, side view of scion; **B**, side of scion that rests against wood of stock; **C**, opposite side from **B**. Right, scions in place. This method differs from ordinary bark grafting (figs. 15 and 16) in that the cut on scion **C** is not centered, and bark is raised on only one side of the slit. Wax all exposed cut surfaces thoroughly, including tops of the scions.

in place by waxed cloth, tape, or string wrapped around the stock. These materials should be cut if they show signs of constricting the stock branch.

The second method of bark grafting (fig. 17) has been widely used, and nearly always with good results. The scions are more easily nailed in place, and there is less danger of injuring them than when the first method is used. A single slit is made in the bark of the stock, but the bark is raised on only one side of the slit. A scion cut as in figure 17 is inserted under the raised bark so that one edge will rest against the undisturbed edge of the slit. As in the first method, a shoulder is usually necessary. The scion is held in place by two nails which pass through it and the raised flap of bark. One or two more nails are driven

through the bark into the wood of the stock near the scion, to pull the bark tightly into place. Occasionally the bark that is supposed to be left undisturbed is accidentally loosened. It must then be fastened with a nail or two. The scions are cut, as in figure 15, except that the cut on the back of the scion (fig. 17, C) is not centered, but is made near the edge of the scion opposite the side that rests against the undisturbed bark of the stock. This uneven cutting allows the raised flap of bark to fit more smoothly on top of the scion.

Figure 18 illustrates the third method of bark grafting, in which two slits are made in the stock, the width of the scion apart, instead of one. These slits should be just long enough so that the scion can be pushed into place without splitting the

Fig. 18. Modified bark grafting. **A**, side view of scion; **B**, side of scion that rests against wood of stock; **C**, opposite side from **B**. Right, scions in place. This method differs from ordinary bark grafting (figs. 15 and 16) in that no shoulder is required on the scions, and two slits are made in the stock instead of one. Wax all exposed surfaces thoroughly, including tops of the scions.

bark. The scions are usually cut, as shown, without a shoulder. The strip of bark between the two slits is raised, and the upper one third to one half is usually removed. However, if very small scions are used the entire strip of bark can be retained to protect them. The scion is then inserted under the bark far enough so that only a little of the cut surface extends above the top of the stock. Two nails hold the scion in place, the upper one driven directly into the scion, the lower one driven first through the strip of bark. The scions for this method can be prepared more rapidly than for the first two methods as there is no shoulder. However, to make the two slits the proper distance apart requires a little more time than to make a single slit. All three methods of bark grafting have given good

results, but considerable evidence shows that the third method, which does not require a shoulder on the scion, is the most satisfactory for the majority of grafters. In the second method, one edge of the scion rests against the undisturbed bark of the stock, whereas in the third method both edges rest against undisturbed bark. Some workers state that better contact of the cambiums of the stock and scion is obtained if the bark on the edge of the scion resting against undisturbed bark of the stock is trimmed just enough to expose the cambium. A grafting experiment in which English walnut scions were placed on black walnut stock indicated, however, that the extra cut has no effect on the number of scions that grow.

Small scions may sometimes be forced

under thick stock bark without a preliminary slit, but it is usually much better to use one of the three methods discussed above.

The lower bud on a scion should be on the outside (figs. 17 and 18), only a short distance above the top of the stock.

Most bark grafting is done on moderate-sized stock branches, but it is sometimes adapted to small branches by making the inner surface of the scion concave (with a curved chisel), to fit around a small branch.

Saw-kerf, or notch, grafting. This has the same advantage as the cleft graft, in that the work can be done over a considerable period. The proper time for grafting is discussed under cleft grafting (p. 24), but most notch grafting is done in January, February, and March. Since the stock is not split, there is less danger from wood-decay organisms than in cleft grafting. Also, curly-grained stock branches that cannot be split properly for cleft grafting may be notch grafted.

Despite these advantages, notch grafting is less common than cleft and bark grafting because it requires considerable skill.

There are two types of notch grafting—deep and shallow. Nails are used to hold the scions in place in the shallow notch but are not necessary for the deep one.

In the first method (fig. 19), the one generally used, a rather deep notch extends approximately to the center of the stock branch. A single cut made with a fine-toothed saw is widened (to fit the scion) with the round knife shown in the photograph. This knife, as used by leather workers, has a blade that is almost the shape of a half circle; but for grafting it should be cut down to the size illustrated. The knife gives best results if one side of the blade is ground flat and the other side beveled as usual. If such a tool is not available, an ordinary grafting knife with a moderately large blade may be used. Most workers find it easier to cut the notch to fit the scion rather than

Fig. 19. Saw-kerf, or notch, grafting. Left, notches cut; center, two views of a scion; right, scions driven into place. All exposed surfaces including tops of scions, should be thoroughly covered with wax, Round knife is used to enlarge notches after single saw cuts have been made.

Fig. 20. Saw-kerf, or notch, grafting. Left, notch cut; center, two views of a scion; right, scions nailed in place. Exposed surfaces, including scion tops, should be thoroughly covered with wax.

cutting the scion to fit the notch. As in cleft grafting, the scions are wedge-shaped, with the outer edge slightly thicker than the inner. The cambium on this thicker, outer edge of the scion is brought in contact with cambium of the stock. Since it is difficult to line them up perfectly, it is suggested that the scions be slanted outward slightly to make certain that the cambiums touch in at least one place. The scions must be carefully but firmly driven into position, preferably with a hardwood stick about 1 inch in diameter.

The second method (fig. 20) resembles the first, except that the notch is very shallow. The scions are usually cut as illustrated, with the outer edge considerably thicker than the inner, and are nailed with the flat-headed wire nails used in bark grafting. Again, care should be taken to match the cambiums of the stock and the scion.

Scions properly placed in thick-barked branches will not be flush with the surface of the stock branch, but will be set in a distance almost equal to the thickness of the stock bark.

The lower bud on the scion should be on the outside (fig. 19), only a short distance above the top of the stock.

Whip, or tongue, grafting. This method, discussed under root grafting (p. 22), is satisfactory for grafting over young trees in which branches are the same size as the scions, or slightly larger. As in other methods of top grafting, all cut surfaces, including scion tips, should be waxed. If tape is used instead of string, wax is needed only on scion tips. The work is usually done in late winter or early spring.

Side grafting. This method is less commonly used than those already discussed. The graft is usually made as in figure 21, but there are many possible modifica-

Fig. 21. Side grafting is most useful for branches about 1 inch in diameter. Left, oblique cut in the stock; center, two views of a scion; right, scion in place. Nails may be used to hold the scion if necessary. If top of the grafted branch is to be removed at once (the usual procedure), a cut should be made just above the point of insertion of the scion, as indicated by broken line. All exposed cut surfaces should be waxed.

tions, including some that require special tools. The method is most useful for branches about 1 inch in diameter—that is, too large for satisfactory whip grafting but somewhat small for cleft, bark, or saw-kerf grafting.

The oblique cut in the stock is made with a chisel or a heavy knife. The scion is usually wedge-shaped, as in the cleft graft. For best contact of cambiums, the scion may be inserted as in figure 21, but the cambiums will touch in at least one place in any event. The stock branch is bent to open the cut, and the scion is inserted. Although the tension of the wood will usually hold the scion in place, small nails or string can be used. The stock branch is generally cut off just above the point of insertion of the scion, and all cut surfaces are waxed. The stock branch should be very carefully removed or the scion will be dislodged.

Some workers allow side grafts to grow a year before removing the entire tops

of the grafted branches, in order to save part of a year's crop while the grafts are growing; this procedure is rarely successful, however.

Sometimes a side graft may be placed on the side of a rather large branch if additional branches are desired in that position. The method of making the graft on large branches varies with the individual worker. Usually, however, a diagonal slit is cut, with a chisel or a saw, through the bark of the stock and a short way into the wood. The scion is driven into place so that the cambiums touch.

Subsequent Treatment of Top-worked Trees

The care of the tree during the first few years after grafting is as important as the operation itself—a fact not commonly realized until breakage begins to occur because of heart rot and weak crotches.

As soon as grafting is completed, the

tree, including scions and waxed areas, should be thoroughly whitewashed to help prevent sunburn. However, if a water emulsion of asphalt is used instead of a hot wax, it must be allowed to dry before the whitewash is applied. Paper bags with holes cut in the corners to provide ventilation are sometimes placed over the grafts to protect the scions from the sun, but experiments have demonstrated that whitewash is more effective. From this time until the trees start growing, an occasional inspection and possibly some re-waxing are all that need be done. When growth begins, however, cracks will appear in the wax and allow decay organisms to enter the wood. Then the grafts must be watched carefully and rewaxed when necessary. When considerable re-

waxing is required, it is advisable to cover newly waxed areas with whitewash.

If water sprouts appearing below the grafts are allowed to grow without restriction, they will usually choke out the grafts. This trouble may be prevented by removing all water sprouts. A better procedure, however, is to thin them out and cut the remaining ones back severely to keep them reasonably small. They will then help protect the tree from sunburn and also manufacture some food for the roots until the grafts are large enough to take over that function. The water sprouts must not be permitted to become too large.

If more than one scion grows on a branch, probably not more than one should be retained permanently, other-

Fig. 22. Apricot grafts after two seasons' growth. **A** and **B** show grafts that are to be saved. These were pruned lightly during the first dormant pruning and have grown very well. **C** and **D** show grafts that were saved temporarily to help heal the stub. These were pruned heavily during the first dormant pruning and have made little growth. All grafts were approximately the same size at the end of the first season's growth.

Fig. 23. Often young grafts need to be supported with laths or strips of wood for a few years.

wise a weak crotch is likely to be formed. The branches to be saved should be pruned as lightly as possible to encourage rapid growth, and those to be removed later should be pruned heavily to keep them from becoming too large (fig. 22). The suppressed branches help to heal over the stub, and are removed when that purpose is accomplished.

If only one scion grows, the square shoulder on the opposite side of the branch will die and probably decay before healing over. More rapid healing will take place if a sloping cut is made downward and away from the side where the scion is growing. The cut surface should be thoroughly waxed.

Often young grafts, especially of walnuts, need to be supported with laths or strips of wood for a few years (fig. 23). If the grafts have made only a small or a moderate amount of growth, they may not require support or any other special treatment. If grafts of stone fruits, such as apricots and plums, grow extremely fast, and the use of supports is considered uneconomical, then the best procedure is to pinch off a few inches at the ends of the grafts after they have grown about 18 inches. Later pinching back may also be desirable. This treatment slows down the growth enough to allow the succulent shoots to mature somewhat and thus keeps them from breaking or bending. Some of the shoots may be thinned out to reduce wind resistance.

Bridge Grafting

Each year many trees are partly or

Fig. 24. Bridge grafting: three views of a prepared scion. Left, side view; center, side of scion that rests against wood of stock; right, opposite side of center view.

Fig. 25. Bridge graft scions in place. The part of the graft where scions are inserted under the bark must be thoroughly waxed over for protection.

completely girdled by rodents, pear blight, or mechanical injury. Often the tree can be saved by bridging over the injured area. In the early spring, as soon as the bark of the injured tree will slip, scions (fig. 24) are inserted into the live tissue (fig. 25) above and below the wound. It is best to gather scions while they are still dormant, and store them in moist sphagnum moss, peat moss, or similar material in a cool place to keep them dormant until they are needed. In some cases, however, it is possible to gather scion wood at the time of grafting. If this is done, any lateral branches growing on the scion wood are removed and the resulting cuts are waxed over. In one experiment, sweet cherry was successfully bridge grafted by this method in early May. Although the use of many scions is desirable, one every 2 or 3

inches is usually satisfactory. The scions are cut wedge-shaped at both ends, but the cut on one side is only about half as long as that on the opposite side. The wedge-shaped ends are then inserted under the bark so that the longest cut surface is next to the wood of the tree. Two slits are made in the bark of the tree to receive the scion, in the manner described for one of the methods of bark grafting (fig. 18). The scions are then nailed in place. If they are made slightly longer than the space to be bridged, they will bow out slightly, and the flat cut surfaces will rest squarely against the wood of the stock. That part of the graft where scions are inserted under the bark must be waxed over. Preferably, the exposed wood in the girdled area should be covered with wax or some of the materials used on pruning cuts, but this is often not done. Remove all buds that start to grow on the scions.

Figure 26 shows how a tree girdled by rabbits was saved by bridge grafting. If suckers or water sprouts appear below the injury, these may be grafted in above, with the same results.

Fig. 26. Bridge grafting saved this tree, which was injured by rabbits. If suckers or water sprouts appear below the injury they may be grafted in above it, with the same good results.

Fig. 27. Inarching. A seedling tree has been planted beside an older tree and grafted into its trunk. All exposed cut surfaces should be waxed.

Inarching

Inarching is a method whereby two plants are made to unite while growing on their own roots. With fruit trees, a young seedling is generally planted beside an older tree and grafted into the trunk (figs. 27 and 28). The usual procedure is to remove, from the trunk of the larger tree, a strip of bark as wide as the seedling trunk and 4 to 6 inches long, and then to lay the seedling trunk in this slit. The vertical cuts are best made with the round knife shown in figure 19. About half of the part of the seedling trunk that lies next to the wood of the tree should be cut away to insure contact of the cambiums. Usually, in order to make the union more certain, the end of the seedling is cut wedge-shaped, as in bark grafting, and shoved under the bark at the top of the slit (fig. 27). The seedling should then be nailed in place, and the cut surface waxed. Some of the shoots that appear on the inarches should probably be saved for

Fig. 28. Two seasons' growth following inarching.

the first growing season, but they must be suppressed by pinching back their tips. After the union is well established, all shoots should be removed. The work described is best done in the early spring as soon as the bark of the injured trees will slip.

When inarching walnuts it is best to allow a portion of the seedling (usually a section containing three or four buds) to extend above the graft. Leaves are allowed to develop on this section during the first growing season. The part above the graft is removed at the end of the first growing season if the union appears to be well established.

Inarching may be used to save trees in which roots have been damaged by pear blight or gophers. If the tree has simply been girdled and the roots are alive below, bridge grafting is the best method.

GRADES OF NURSERY TREES

Under authority of the Agricultural Code of California, the Director of the California Department of Agriculture

has established by regulation grade-sizes for deciduous fruit and nut trees, grapevines, and rose bushes.

The regulation specifies that deciduous fruit and almond trees sold bare-root in lots of ten or more of one variety shall be labeled with a grade-size. Trees shall be graded by caliper and are to be measured 2 inches above the center of the bud union or, if not budded, 2 inches above the crown.

- *Yearling trees (2-year-old roots) and older* shall be graded in the following sizes:

$\frac{1}{4}$ inch to $\frac{5}{16}$ inch; $\frac{5}{16}$ inch to $\frac{3}{8}$ inch; $\frac{3}{8}$ inch to $\frac{1}{2}$ inch; $\frac{1}{2}$ inch to $\frac{5}{8}$ inch; $\frac{5}{8}$ inch to $\frac{3}{4}$ inch; $\frac{3}{4}$ inch to 1 inch; 1 inch and up. Less than $\frac{1}{4}$ inch shall be graded "sub-standard."

- *June buds (1-year-old roots)* shall be graded in the following sizes:

$\frac{3}{16}$ inch to $\frac{1}{4}$ inch; $\frac{1}{4}$ inch to $\frac{5}{16}$ inch; $\frac{5}{16}$ inch to $\frac{3}{8}$ inch; $\frac{3}{8}$ inch to $\frac{1}{2}$ inch; $\frac{1}{2}$ inch to $\frac{5}{8}$ inch; $\frac{5}{8}$ inch to $\frac{3}{4}$ inch; $\frac{3}{4}$ inch and up. Less than $\frac{3}{16}$ inch shall be graded "sub-standard."

Walnut and pecan trees sold bare-root in lots of ten or more of one variety shall be labeled with a grade-size. Trees shall be graded by caliper and are to be measured 3 inches above the center of the bud union or, if grafted, 3 inches above the top of the original grafting scion.

- *Yearling trees (2-year-old roots) and older* shall be graded in the following sizes:

Under $\frac{3}{8}$ inch; $\frac{3}{8}$ inch to $\frac{1}{2}$ inch; $\frac{1}{2}$ inch to $\frac{5}{8}$ inch; $\frac{5}{8}$ inch to $\frac{3}{4}$ inch; $\frac{3}{4}$ inch to 1 inch; 1 inch to $1\frac{1}{4}$ inches; $1\frac{1}{4}$ inches and up.

Grade-sizes for grapevines and rose bushes have also been established by regulation. Copies of the current regulation pertaining to grade-sizes may be obtained from Nursery Service, California Department of Agriculture, 1220 N Street, Sacramento, California.

WAXES AND OTHER GRAFTING MATERIALS

Most grafting waxes are a mixture of resin, beeswax, lampblack, and either linseed oil or tallow. Some combinations of these are soft enough to be applied with the hands, but in California the

general practice is to make the wax fairly hard, melt it over a fire, and apply it with a brush.

A satisfactory wax consists of 5 pounds of resin, $\frac{3}{4}$ pound of beeswax, $\frac{1}{2}$ pint of raw linseed oil, 1 ounce of lampblack, and $1\frac{1}{2}$ ounces of flake glue. Melt resin first, then add and melt beeswax. Remove from flame, and stir in linseed oil and lampblack. Heat glue in a double boiler with just enough water to dissolve it. The glue should then be added slowly (while stirring) to the wax, which has been allowed to cool somewhat but is still a liquid. If glue is added rapidly while the wax is still very warm, the whole mass will boil over.

Most grafting waxes contain lampblack (or, occasionally, a red pigment) so that the different color makes it easy to determine when grafts are covered.

If only a small amount of wax is required, it is more convenient to buy a prepared product. Water emulsions of asphalt are available under various trade names, such as Treheal or Tree Seal. They are easily applied cold and are usually satisfactory, although they may be washed off if rain occurs before they have thoroughly dried. Similar materials containing mineral solvents should not be used for grafting.

Waxed cloth and string may be prepared by dipping muslin or other cloth and light twine in hot grafting wax. The lampblack is usually omitted when the wax is used for this purpose. Waxed cloth is commonly prepared by dipping the material in melted beeswax.

Nurseryman's tape or budding tape usually comes in rolls $\frac{1}{2}$ inch wide. It should be used when available, but cloth masking tape which is manufactured for use by painters also has given very good results.

LAYERING

Layering is the operation of rooting stems while the stems are still attached to the parent plant.

Fig. 29. Tip layer of blackberry. Arrow points to the tip of a layered cane which will develop into the top of the new plant. Ends of canes are covered with earth during late summer.

Simple layering. This method consists of laying down a branch and covering part of its length with soil, leaving the tip uncovered. Roots often form more readily if the buried portion of the branch is girdled or notched. In the dormant season the rooted shoot may be severed from the parent plant. This method may be used in propagating small numbers of plants of various shrubs and of grapes, but not in producing most deciduous fruits commercially. However, it is at present the most common way of propagating filberts.

Tip layering. The common way to propagate trailing blackberries, dewberries, and black raspberries is by tip layering. The ends of the canes are covered with a shovelful of earth during the latter part of the summer. The covered portion sends down roots and forms a plant that can be set out the following spring (fig. 29). About 6 inches of the original layered cane are left attached to serve as a handle, and to act as a marker or guide in cultivating until new shoots appear.

Mound, or stool layering. Before growth starts in the spring, the mother plants are cut back close to the ground. Soil is mounded around the bases of the new shoots as they grow during the spring, but the tips are not covered. The mound is built up to a height of 8 to 12

inches. Roots arise from the bases of the new shoots, growing into the mound of soil. If mounds are kept moist through the summer, the shoots are usually well-rooted by winter when soil is removed and rooted shoots are cut off. These are often lined out in the nursery row the second spring, and grown an additional year to produce stronger plants. Mound layering is used in the commercial production of gooseberries, currants, quinces, and certain vegetatively-propagated plum and apple rootstocks.

Trench layering. This consists of bending over the whole top of the plant and pegging it down in a trench 2 or 3 inches deep. The usual practice is to plant trees with 1-year-old tops in the winter, inclining the trunk at an angle of 30 to 45 degrees from the horizontal. The following winter, after one season's growth, the top is layered. Any branches that cannot be held flat against the bottom of the trench should be removed. In the spring when the new shoots are about 3 inches tall, fine soil is shoveled around their bases, and this process is repeated at intervals until the layered top is covered to a depth of about 6 inches. With more difficult-rooting species, all layered parts should be covered about an inch deep with fine soil just before the buds open. In early winter, after shoots have grown one season, the soil is drawn away from

Fig. 30. Trench layering. Soil removed to show plant in position. Rooted shoots produced in one season. The whole top of plant is bent over and pegged down in a trench 2 or 3 inches deep.

the layers, and the rooted shoots (fig. 30) are detached. A few shoots fail to root each year, and these may be laid down to supplement the original layered tree. Old layers are left uncovered until the following spring, when the program of the previous year is repeated.

Trench layering has been used mostly for the propagation of apple and plum rootstocks, but has not been used much in California.

Air layering (pot layering or Chinese layering [marcottage]). This is an ancient method, sometimes used in propagating certain plants that are difficult to start as cuttings and that have an upright growth habit not adaptable to the other types of layering. Although some varieties of fig, lichee, persimmon, crab-apple, highbush blueberry, and plum have been propagated in this manner, it is not used commercially in California. In the modern procedure of air layering, a ball of some moisture-holding material, such as peat moss or sphagnum moss, is placed around a section of a stem and wrapped tightly with polyethylene plastic sheeting (fig. 31). Roots are initiated at this point and grow into the moss.

The layering may be done when growth starts in the spring, on 1-year-old wood, or it may be made in mid-

summer, using partially mature, current season's growth. In some plants, roots will form during the first summer, but for others a good root system will not develop until the end of the second year.

The layer should be made on shoots $\frac{1}{2}$ to 1 inch in diameter, and be placed about 18 inches back from the terminal end. The branch may be girdled at this point by removing a section of bark $\frac{1}{2}$ to 1 inch in width, or it may be partially cut through. Root formation may be stimulated by rubbing a root-promoting powder, or brushing a concentrated dip root-promoting solution (see page 47), on the cut surfaces. The slightly damp (not wet) moss is made into a compact ball about 4 inches wide and 6 inches long, placed on the branch and centered over the girdling cut. A sheet of polyethylene, marketed commercially for this purpose as Airwrap, is wrapped securely about the ball and tied at each end. Electrical tape makes a satisfactory tying material as it can be lapped at the upper end to keep rain from seeping down the branch into the layer. The plastic should be lapped on the underside so that rain does not penetrate and wet the moss excessively, as this would cause the bark to rot. No further attention is needed until roots are formed—

Fig. 31. Preparing an air layer on a fig branch. Top: a 1-inch girdling cut is made around stem just below point where rooting is to take place. Bottom: girdled section is covered with ball of damp, shredded sphagnum moss wrapped with a sheet of polyethylene plastic; ends are tied with tape wrapped to keep rain from getting under plastic covering.

they can be seen through the plastic. Generally it is unnecessary to add water, as the polyethylene effectively prevents water loss.

After a substantial root system has developed, the branch is cut off just below the ball of moss, the polyethylene is re-

moved, and the layer can be planted. (For deciduous species, removal should be delayed until the dormant season when the layer can be more safely removed.) The ball of moss containing the roots should not be disturbed. Some of the leaves must be removed and the new plant held for a time under cool, humid conditions until it becomes re-established.

RUNNERS

This method of propagation is a natural type of layering. Runners of the strawberry, which is propagated in this manner, root at every other node, or joint, without assistance if soil is kept moist (fig. 32). Buds at the rooted nodes send out leaves, thus forming a new plant which, in turn, produces runners and additional runner plants. A single strawberry plant may produce one hundred or more runner plants in one season.

Some everbearing strawberry varieties, such as the Rockhill, seldom produce runners and must be propagated by dividing the crown into several pieces, each capable of developing into a new plant.

CUTTINGS

Propagation by cuttings consists of placing a detached piece of the mother plant, such as a stem, root, or leaf, under conditions favorable for root and shoot development. Stem cuttings are the most important, and include the hardwood, semihardwood, and softwood types.

Hardwood cuttings. These consist of sections of the stem usually taken from the previous season's growth although with some species, such as the fig and olive, wood up to 2 or 3 years old can be used. For deciduous species, cuttings are made after the leaves drop, from late fall to early spring. The length of the cuttings varies with the species, ranging from 5 to 15 inches. Each cutting should include at least two nodes. Figure 33 shows some typical examples. Roots ordinarily arise

Fig. 32. Propagation of strawberry plants by runners. **A**, parent plant; **B**, new plants formed at nodes, or joints. New plants that are produced occur only at every other node.

in the vicinity of the lower node, or nodes, while the shoot originates from one of the uppermost buds. In species with short internodes it is immaterial where cuts are made in relation to the nodes, but if inter-

nodes are long the basal cut should be about $\frac{1}{2}$ inch below a node and the top cut about 1 inch above a node.

A number of varieties of fruit species are propagated commercially by hard-

Fig. 33. Examples of hardwood cuttings. **A**, grape; **B**, currant; **C**, gooseberry; **D**, fig; **E**, quince.

wood cuttings and are thus grown "on their own roots." No graft or bud union is involved. These are varieties of grape, currant, gooseberry, fig, quince, pomegranate, and olive. In addition, a number of rootstocks are propagated in this manner, to be budded or grafted later to a named fruit variety. These include certain plum rootstocks, such as Myrobalan 29C and Marianna 2624; nematode- and phyloxera-resistant grape rootstocks; types of the quince used as a dwarfing stock for pears; and certain clonal apple and pear rootstocks.

There are several methods of handling hardwood cuttings of deciduous fruit species. The cutting material may be gathered in the fall—about mid-November in California—made into cuttings, and planted immediately. With some species it is advantageous to treat hardwood cuttings with a root-promoting chemical before planting (page 47). Better rooting of some plants is more often obtained with fall planting than with spring planting, especially in regions having mild winters. In areas having severe winters, cold damage may occur to fall-planted cuttings, and freezing and thawing of the soil may cause cuttings to heave out of the ground. Rodent injury in winter may also be a problem.

Another method commonly used is to prepare cuttings in late fall or early winter and store them in callusing beds for planting in the nursery row in early spring. Bundles of cuttings may be packed in some moist material (such as sawdust, shingle tow, or peat moss) in large boxes, and kept in an unheated outdoor building or a cool cellar until planting time. Temperatures of 40° to 60° F are desirable.

An old method still used occasionally is to bury bundles of cuttings in a well-drained, outdoor pit in the soil. The bundles are placed vertically, and inverted—that is, the basal ends of the cuttings are toward the top of the pit and the terminal ends are at the bottom.

The soil is then packed loosely around the bundles and filled in over the base of the cuttings for several inches. Inverting the cuttings places the basal ends nearer the surface where the soil is warmed by the sun. The increased temperature promotes development of roots. The terminal ends, being buried more deeply, would presumably be cooler—and this has the desirable effect of retarding activity of the buds.

Cuttings stored in any type of callusing beds should be watched closely, especially with the coming of warm spring days. If root and shoot activity appears, remove the cuttings immediately and plant them.

Another practice with easily-rooted species, especially in areas having mild winter climates, is to gather cutting material in late winter—but before bud activity begins—prepare the cuttings, and plant them in the nursery row immediately. This is only possible at times during the winter when the soil is sufficiently dry to permit such planting.

Where cold storage facilities are available, cutting material of easily-rooted species may be gathered at any time during the winter, wrapped in packages containing some moisture-holding material, such as peat moss or sphagnum moss, and held at 32° F until spring. At that time the cuttings are made and planted immediately.

For difficult-to-root species, such as the Old Home pear, good results have been obtained in areas having mild winters by taking the cuttings in early November, treating them with indolebutyric acid at 100 ppm (parts per million) for 24 hours (see page 47), storing them in slightly damp peat moss at about 70° F until roots first appear (about 3 weeks), and then planting them in the nursery.

Another method for difficult species is to treat the cuttings with indolebutyric acid as indicated above and then place them upright in boxes of damp peat moss over bottom heat (70° F) in an unheated

Fig. 34, Left, typical gooseberry cuttings; right, a rooted gooseberry cutting after a year's growth.

open shed, so that the bases of the cuttings are warm but with the top buds exposed to the winter cold. The cuttings should be planted in the nursery when roots first appear.

As a rule, cuttings are planted so that only one bud is above the ground level, and are placed 3 to 4 inches apart in the

nursery row. Figure 34 shows typical gooseberry cuttings before rooting, and a similar rooted cutting after a year's growth.

Semihardwood cuttings. This is a type of stem cutting used in propagating certain kinds of broad-leaved evergreens. The olive is propagated commercially in

this manner. Other fruit plants which can be propagated by semihardwood cuttings, although not commercially, include certain citrus species, macadamia, and some avocados.

These are leafy cuttings which must be rooted under conditions of high humidity, such as in mist propagating beds (see page 45). Semihardwood cuttings can ordinarily be rooted at any time of year, but for plants which have distinct flushes of growth it is best to take cuttings following a period of growth activity after the wood has become partially matured. Olive cuttings root best when taken in mid-summer.

Rooting of semihardwood cuttings is usually markedly promoted by treatments with root-promoting "hormones" (see page 47).

Softwood cuttings. These are leafy stem cuttings made from young, succulent spring growth. Although not usually used commercially, softwood cuttings of a number of fruit species can be rooted if they are started in mist propagating beds and treated with root-promoting "hormones." Cuttings which have been rooted in this manner include some varieties of the peach, pear, plum, apple, apricot, cherry, walnut, and grape. In fact, a number of plants which are commonly considered very difficult to propagate by cuttings can be started by using softwood cuttings under mist.

Root cuttings. These are small sections of roots which, when planted, produce a new shoot system and a renewal of growth of the existing root piece. Success is more likely with root cuttings if they are taken from young plants, not over 2 or 3 years old. Plants which produce suckers from the roots ordinarily can be propagated readily by root cuttings. Fruit species started in this manner include red raspberry, trailing and upright blackberries, quince, and some apple rootstocks.

Cuttings can be made from roots of various sizes, even very small roots. They

are cut into sections 2 to 4 inches long, and may be planted either horizontally, about 2 inches deep in the nursery row, or vertically with the top just below the surface of the soil. Red raspberry and blackberry root cuttings are ordinarily planted horizontally. In vertical planting, the end of the root piece which was nearest the crown of the plant should always be up. The best time to take the cuttings is in late winter or early spring before growth starts. They may be made and planted immediately, or stored in a cool, moist callusing bed until they are planted in the spring.

Leaf-bud cuttings. This type of cutting consists of a leaf blade and petiole, together with a short section of the stem to which the leaf is attached, and includes the axillary bud at the base of the petiole. As with any type of leafy cutting, leaf-bud cuttings must be rooted under high-humidity conditions, such as in a glass-covered frame or under mist. Black raspberries and the various types of blackberries (fig. 35) can be started in this manner. The red raspberry, however, apparently cannot be propagated by this type of cutting.

ROOTING MEDIA

Hardwood cuttings without leaves are best planted in a fertile, sandy loam soil free of nematodes and other pests, such as crown gall or oak root fungus. A sandy-type soil is desirable as it is generally well aerated—a condition that promotes good rooting of the cuttings. In addition, the soil can be worked soon after rains, thus facilitating planting and digging operations.

Leafy types of cuttings started in special propagating beds or frames require a rooting medium that is well aerated, has good drainage yet holds moisture fairly well, and is free of decaying leaves, twigs, and other organic matter which would harbor disease-producing organisms.

Several materials are widely used for

Fig. 35. Blackberry leaf-bud cuttings, showing a well-developed root system.

rooting media, and all give satisfactory results.

Sand. A medium-grade washed sand, such as that used in the building trade, is the most suitable. Sand has a rather poor water-holding capacity, and requires frequent watering.

Sand-peat moss mixture. The peat moss compensates for the poor water-holding capacity of sand. Quite often a more desirable fibrous root system forms on cuttings in this mixture than is the case when using straight sand. Peat moss alone is sometimes used as a rooting medium for acid-requiring plants.

Vermiculite. This is useful as a rooting medium and is available in several particle sizes. It is a micaceous mineral—chemically, a hydrated magnesium-aluminum-iron silicate—which is expanded by high temperatures to form porous, lightweight, sterile particles with a high water-holding capacity. Vermiculite should not be compressed in any way when it is wet as this will destroy its porous structure. Mixtures of vermiculite

and sand or vermiculite and perlite are very satisfactory rooting media, especially in mist propagating beds (see page 46).

Perlite. This is a gray-white material of volcanic origin which has proved useful for rooting cuttings, especially when mixed with vermiculite or with peat moss. It is very light in weight but has a good water-holding capacity, and is practically sterile as a result of the high processing temperatures.

MIST PROPAGATION FOR LEAFY CUTTINGS

The practice of rooting cuttings under water mist sprays (fig. 36) not only keeps the humidity around the cuttings at a high level, but also lowers the temperature of the leaves, thus helping to reduce undesirable water loss. Propagation beds using mist equipment are ordinarily set up in the greenhouse, for summer and winter use. Nozzles over the beds are spaced to produce a fine, foglike spray that completely covers the bed.

Fig. 36. Commercial mist propagation bed in a greenhouse.

Intermittent mist seems to be more satisfactory for most plants than does continuous mist. Only enough water to keep a film on the leaves is necessary. Applications of water in excess of this seem to be of no value; they tend to reduce the temperature of the rooting medium to undesirably low levels and to waste water. The best practice for most plants is to apply mist only during daylight hours, and then only intermittently. The on-and-off intervals can be short, with the mist allowed to wet the leaves thoroughly, then being shut off until the leaves start to dry. Various automatic devices are used for controlling the water.

Several types of spray nozzles are available; two commonly used ones are the whirling-action type, and the deflection type. The first produces an evenly-distributed fine spray, and uses a relatively small amount of water. The mist is produced in this nozzle by water passing through small grooves set at an angle to each other.

The deflection nozzle develops a mist

by means of a fine stream of water striking a flat surface. The larger aperture used in this type greatly reduces clogging but uses considerably more water. This nozzle usually covers a greater area than the other type, and thus fewer are needed.

There are several methods of placing the water pipes to which nozzles are attached. One is to lay the main feeder pipe down the center of the bed below, at, or above the surface of the rooting medium, with the nozzles at the end of risers from this pipe. This method eliminates dripping because excess water runs back down the riser pipe. Another method is to place the feeder pipe well above the cuttings—either one pipe down the center of the bed or two pipes, one along each side—with the nozzles directed downward into the bed. Whatever arrangement is used, the nozzles should be placed close enough together and the water pressure should be high enough so that the entire bed is under the mist. Rooting is likely to be unsatisfactory unless the mist actually wets the leaves.

The frequent operation of the water line to supply an intermittent mist requires the use of an electrically-operated solenoid valve, preferably the normally-open type. With this valve a power failure would simply mean a continuous mist, but with a normally-closed solenoid a power failure would cut off the mist entirely and could result in death of the cuttings.

An electrically-operated control uses two timers acting together. One timer turns the entire system on in the morning and off at night. The second timer operates the system during the daylight hours to produce an intermittent mist at any desired combination of timing intervals—about 10 seconds on and 90 seconds off is generally satisfactory. This type of control mechanism is relatively foolproof, and although it does not automatically compensate for variations in humidity conditions it can be adjusted to give entirely satisfactory results.

Various difficulties often arise in operating a mist propagating bed. One of these is the lack of sufficient water pressure to operate the nozzles properly. This can be overcome by installing a small, electrically-operated rotary booster pump between the water source and the solenoid valve. If there is much sand in the water, it is advisable to install filters in the supply line to reduce clogging of the nozzles.

In propagating cuttings under mist it is essential that a well-drained rooting medium be used. In addition, the bed should either be raised, or equipped with drainage tile to provide for quick removal of excess water.

Once the cuttings are rooted they should be moved promptly from the very moist conditions of the mist to a drier environment, but this must be done carefully. One way of doing this is to withhold the mist gradually—decreasing the “on” periods and increasing the “off” periods—until cuttings are able to survive without mist. Rooted cuttings may

then be potted or left in the rooting medium until the dormant season, when it is safer to dig them.

Mist propagation permits the use of soft, succulent, fast-growing cutting material, taken early in the season, which is more likely to root than is more mature hardened wood taken later in the season (fig. 37). This technique is not as yet used in the commercial propagation of most fruit plants.

USE OF GROWTH REGULATORS IN ROOTING CUTTINGS

Some chemicals, such as indolebutyric acid, will under certain conditions promote root initiation on hardwood, semi-hardwood, and softwood stem cuttings as well as on leaf and leaf-bud cuttings.

Treatments with these chemicals, while not always effective, often cause a greater percentage of the cuttings to root, speed root formation, and produce a higher number of roots per cutting. Excessive concentrations can be injurious. These chemicals are not recommended for use with root cuttings.

Commercial preparations are available (generally in powder form) in which the active ingredients are dispersed in talc. The chemicals can also be obtained as pure crystals, from which the propagator can prepare his own rooting solutions.

Powder dip method. Powders are available commercially in various strengths, and should be used according to directions. The basal ends of the cuttings are dipped into the powder, enough of which generally adheres to be absorbed and effective.

Dilute solution, 24-hour soaking method. Relatively dilute solutions of the chemicals are prepared, in which bundles of the cuttings are soaked for 24 hours and then set in the rooting medium. The basal ends of the cuttings

Fig. 37. Examples of cuttings of difficult-to-root fruit species treated with a root-promoting substance (indolebutyric acid) and rooted under mist. Top left, Fay Elberta peach; top right, Santa Rosa plum. Lower left, Tilton apricot; lower right, Bartlett pear.

To prepare 1 gallon of an approximate 100 ppm solution of indolebutyric acid, measure a level $\frac{1}{4}$ teaspoon of the chemical, dissolve it in a small amount of alcohol (ethyl or isopropyl), and add to the water, stirring thoroughly.

should be immersed in the solution to a depth of $\frac{1}{2}$ to 1 inch. The concentrations used vary from 15 to 200 ppm (parts per million) depending upon the species. A strength of 50 to 100 ppm of indolebutyric acid is effective in promoting rooting of softwood, semihardwood, and hardwood cuttings of many plants.

Fig. 38. Suckers of red raspberry. **A**, parent plant; **B**, suckers in different stages of development.

Concentrated-solution dip method.

A rather concentrated solution—500 to 10,000 ppm—is prepared in which the basal $\frac{1}{2}$ inch of the cutting is immersed for about 5 seconds. Large bundles of cuttings can be dipped at one time and then set immediately in the rooting bed. It is always advisable to have fresh basal cuts at the time the cuttings are dipped. For hardwood cuttings, a concentration of about 2,000 ppm is recommended, but

for softwood and semihardwood cuttings, higher concentrations (4,000 to 6,000 ppm) are generally more effective.

SUCKERS

Red raspberries, upright blackberries, filberts, and the Stockton Morello cherry (a rootstock for cherries), can be propagated by suckers. The suckers, together with some roots, are removed from the parent plant during the winter (fig. 38).

To prepare a 4,000-ppm solution of indolebutyric acid, dissolve a level $\frac{1}{4}$ teaspoon of the pure crystals in $3\frac{1}{3}$ fluid ounces of 50 per cent alcohol (ethyl or isopropyl).

METHODS OF PROPAGATING VARIOUS FRUIT PLANTS

Quince, fig, grape, currant, gooseberry, olive, and pomegranate, and certain plum rootstocks, such as Myrobalan 29C and Marianna 2624, are propagated by hardwood cuttings. Mound, or stool, layering may also be used for quince, currant, and gooseberry. The olive can

also be propagated by semihardwood cuttings.

Trailing blackberries, dewberries, and black raspberries are commonly propagated by tip layering, although they can also be started by leaf-bud cuttings.

Red raspberries and upright black-

berries are usually propagated by suckers or, if these are not plentiful enough, by root cuttings.

The common varieties of strawberries are easily propagated by runners.

Pear, apple, cherry, peach, nectarine, apricot, almond, and plum are usually budded on either clonal or seedling rootstocks, using the T, or shield, method. This is generally done in late summer or in the fall, but June or spring budding may also be practiced.

Walnut and pecan are budded on seedling rootstocks by the patch or flute method, or they may be crown grafted.

Fruit trees are top-worked (that is, top grafted or top budded) for various reasons. Sometimes the variety planted may not find a satisfactory market even though the trees are growing well; sometimes seedling trees in orchards or yards may be worked over to established varieties; and sometimes the home orchardist desires to graft or bud a number of varieties or kinds of fruit on one tree (table 1, page 20, shows combinations possible). Small branches of pear, cherry, apple, peach, nectarine, apricot, almond, plum, and fig may be budded in the summer by the T, or shield, method. For walnut and pecan, the patch or flute method should be used. Small branches of any common deciduous fruit plant may also be whip- or tongue-grafted—usually in January, February, or March. For branches about 1 inch in diameter, side grafting is reasonably satisfactory.

Cleft graft, bark graft, and saw-kerf, or notch, graft are suitable for larger branches up to 3 or 4 inches in diameter. All these methods have given good results with apple, pear, cherry, apricot,

almond, plum, persimmon, and fig. Each has advantages and disadvantages which should be considered before making a final selection.

Some propagators have successfully cleft- and saw-kerf-grafted walnuts and pecans, but the average worker has better results year after year with the bark graft. The third method of bark grafting described in this circular (page 28) is recommended for the walnut and pecan.

Good results cannot be expected when grafting old, weak trees, or trees in which growth has been seriously hampered by lack of water, nitrogen, or other essentials; this statement applies especially to the peach and nectarine. Young, vigorous peach and nectarine trees may be successfully cleft-, bark-, or saw-kerf-grafted; but on old, weak trees the grafts will often fail to grow. In general, T, or shield, budding and bark and saw-kerf grafting have given better results with peach and nectarine than has cleft grafting.

Bark grafting can be used in top-grafting grapes. It is also the most suitable method for top-grafting olives.

Simple layering is the most common way of propagating filberts.

Grapes are propagated by hardwood cuttings. If there are root-knot nematodes or phylloxera in the soil, desired varieties may be whip- or machine-bench-grafted before planting in the nursery, or chip-budded or field grafted in the vineyard on resistant rootstocks.

Bridge grafting and inarching are excellent methods which can be recommended for saving apple and pear trees and, to a lesser extent, other species whose trunks or roots have been injured.

To simplify the information, it is sometimes necessary to use trade names of products or equipment. No endorsement of named products is intended nor is criticism implied of similar products not mentioned.

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ME!

A FARM PRODUCT?

Well, not exactly—you can't grow automobiles on farms, but farm products are essential in manufacturing them. Consider the annual agricultural needs of just one major automobile company.

. 900,000 bushels of corn
736,000 bushels of flax-
seed
74,000 bales of cotton

or, in terms of approximate acreage:

. 15,000 acres of corn
80,000 acres of flax
78,000 acres of cotton

During the same period this company used products derived from 364,000 sheep and 36,000 cattle—plus many other items such as hog bristles and beeswax. In all, produce equivalent to the output of 1,000 good-sized farms is needed yearly. No wonder a top executive in the automotive industry has said: "Our plants, here and throughout the world, would have to close their doors in a few days if their flow of agricultural materials were to stop."

Supplying America's countless industries—and feeding the nation bountifully—makes agriculture America's biggest and perhaps most important business. That is one reason why anything which affects agriculture affects everybody.