CHAPTER 4

VEGETATIVE PROPAGATION

Reproduction of pines through the union of the sperm and the egg was discussed in the preceding chapter, followed here by information on producing new plants from grafting or rooting scions. *Vegetative reproduction* usually refers to production of new plants from parts such as pollen grains, but such techniques have not been developed for southern pines.

Research in vegetative propagation of southern pines has been directed toward development of a variety of methods for multiplying pines to produce genetically uniform trees. Clones have been grafted in seed orchards, plus trees have been preserved in breeding banks, and trees produced for physiological studies such as effects of fertilization or irrigation. Lack of a simple method of propagating southern pines has handicapped certain types of tree improvement research. Clonal plantations similar to those used for growing cottonwood might be feasible for certain high-value strains of pine if methods of vegetative propagation were available.

In this chapter, methods of propagation used in seed orchards will be emphasized. No attempt will be made to summarize results of individual studies or work with various species.

Some of the first papers on vegetative propagation of southern pines in relation to tree improvement projects were given at tree improvement conferences beginning in 1953 (Zak 1953; Mergen 1953c). Subsequent papers were published by Zak (1955a), McAlpine (1957), Reines (1957), Wang and Perry (1957), Perry and Wang (1957b), Johansen (1957), and Grigsby (1957). Articles at tree improvement conferences dealing with vegetative propagation in relation to seed orchard establishment and management were by Otterbach (1963), Wynens (1965), and Goddard (1967). Vegetative propagation in genetics research and forest tree improvement was extensively discussed by Nienstaedt *et al.* (1958), the biological basis for the propagation of woody plants from cuttings was studied by Komissarov (1964), and vegetative propagation of pines via needle fascicles by Girovard (1971).

GRAFTING

Grafting scions or twigs from special trees to seedlings of the same species is the most commonly used propagation method for southern pines. The percentage of successful grafts is high if workers are well trained, but the process is complicated.

Grafted scions do not have their own roots as do rooted cuttings or air layers, but there may be opportunities to obtain some benefits from using stock plants of different races, varieties, or species of pines. The stock seedlings are usually vigorous and in good condition to nourish the scion until union of tissue is complete.

Scion Material

Although any tissue or part of a tree that has a vegetative bud can be grafted, twigs are most commonly used for seed orchard clones.

Grafting Scions

Attaching the scion to the stock stem in a vertical, terminal position is the most common method used, but some success has been achieved by attaching it at different locations and by different shape cuts in the tissue. The same method of grafting seems applicable to various southern pine species.

Methods of grafting and success obtained for southern pines have been discussed by Chase and Galle (1954), Mergen (1953b, 1954a, 1954b, 1955b), Reines and Greene (1956), Jackson and Zak (1949), and Smith and Smith (1968).

Instructions for vegetative propagation of slash pine were prepared in illustrated form in a booklet entitled *How to Root and Graft Slash Pine*, by Mergen and Rossoll (1954). Methods illustrated were cleft graft with succulent tissue, grafting with dormant scions (bottle graft), veneer graft, and inarching seedlings into mature trees (fig. 41a-f).

The Georgia Forestry Commission in connection with the seed orchard project developed effective methods for nursery bed grafting of both loblolly and slash pines (Wynens 1965). The details are illustrated here (figures 42 to 44). The first requirement of the method is that root-pruned 1–0 stock plants with 1- by 1-foot spacing and a diameter approaching the diameter of the scion be grown. Other requirements were: irrigation; a moisture retainer such as the polyethylene bag, vented for heat release, covering two-thirds of the plant; outside of the polyethylene bag, some type of shade or insulator such as aluminum foil or kraft bag; and, grafting beginning as early in the spring as weather conditions permit and discontinuing by the last of May.

A large percentage of successful unions is obtained when stock and scion are in a succulent condition. The method described is suitable for grafting directly on stock growing in the field, or for potted plants in a lathhouse, or greenhouse. The best time to graft with succulent material is during the later part of April, May, June, or early part of July. Grafting can be started as soon as the leader has added several inches of new growth, even though not all the needles of the new growth have ruptured the sheath.

As in any type of grafting, the outcome greatly depends upon the condition of the stock. Use only trees as understock which are healthy and in a vigorous growing condition. When potted plants are used, best results will be obtained if they have been in the container for at least six months prior to being used. Trees 1 to 3 years old make good understocks. For best results select a stock plant with diameter at the place of grafting the same as that of the scion.

The grafting knives and clippers need to be very sharp and kept in good condition during the entire grafting work. Wipe blade of knife frequently with a wad of cotton soaked in alcohol to remove gum (oleoresin). A clean sharp knife will slice the cells instead of tearing the tissue.

If grafting is done on potted stock, place the grafting bench in the shade.

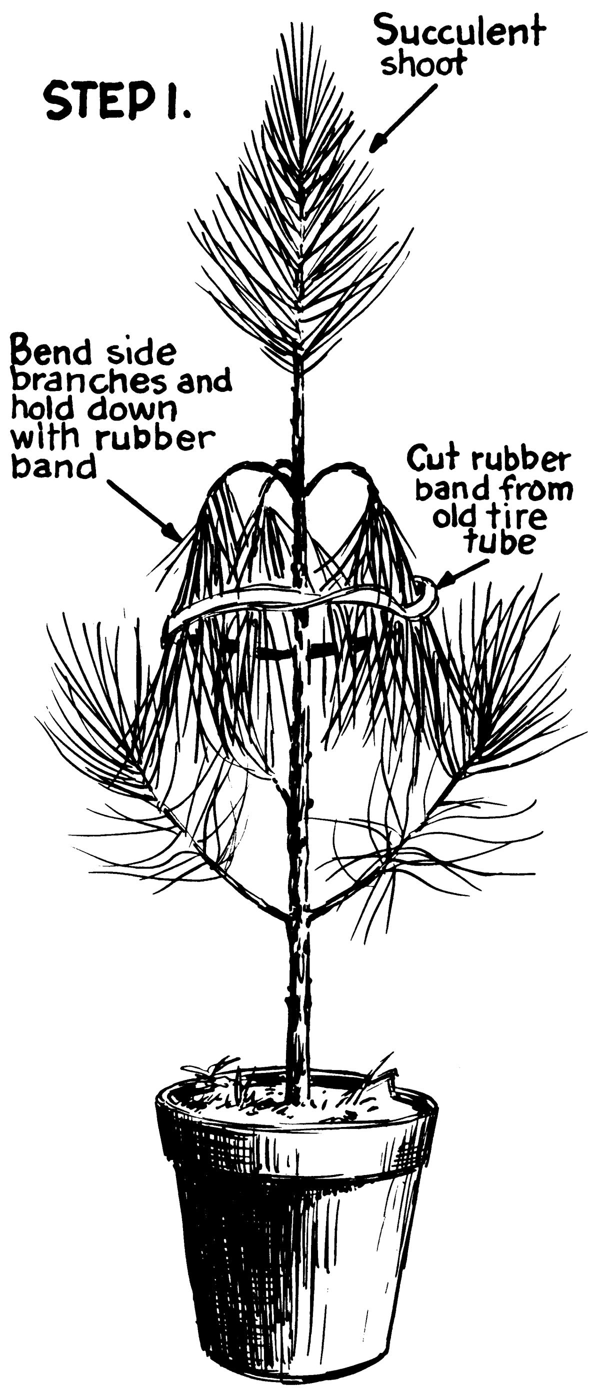
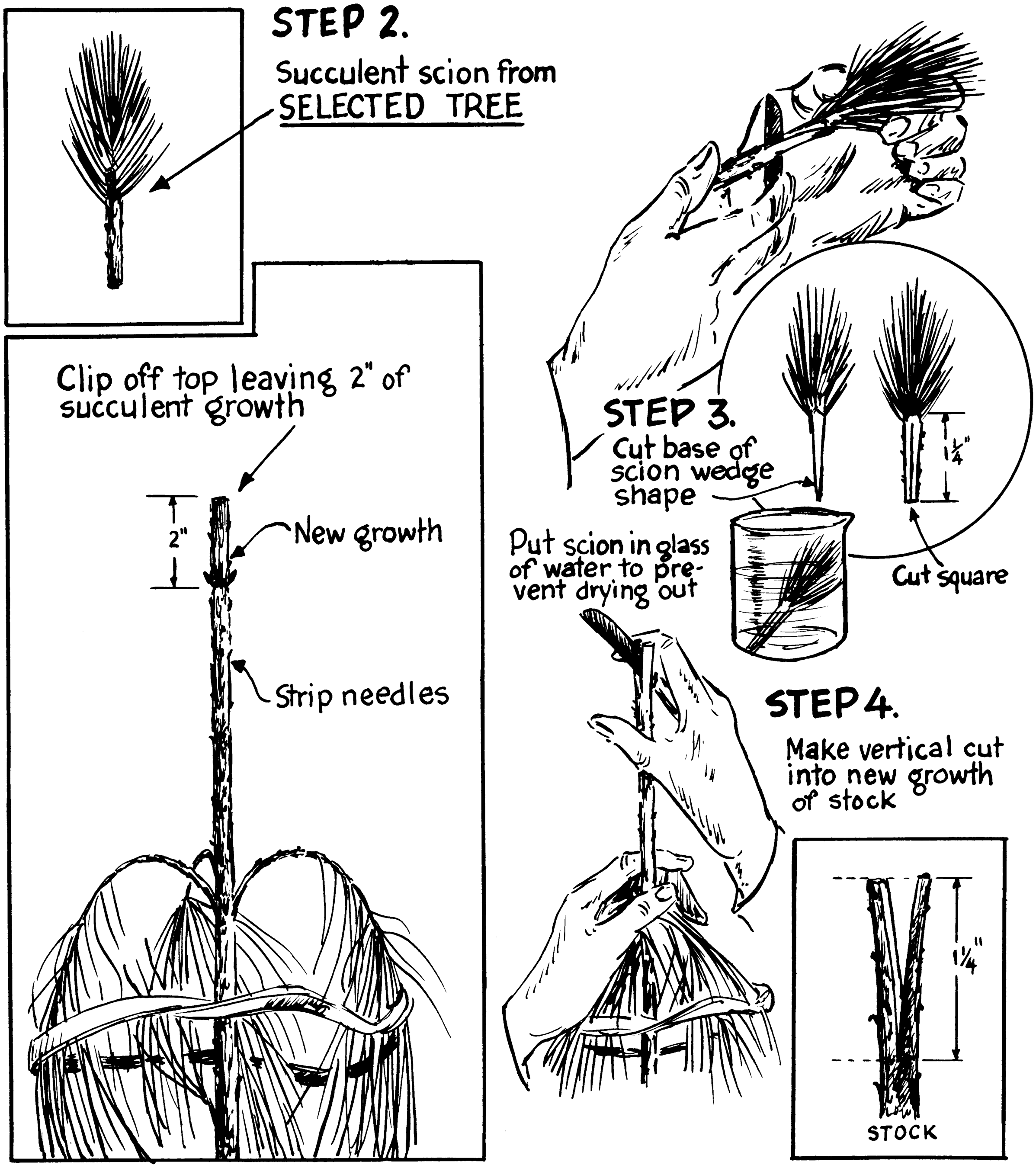
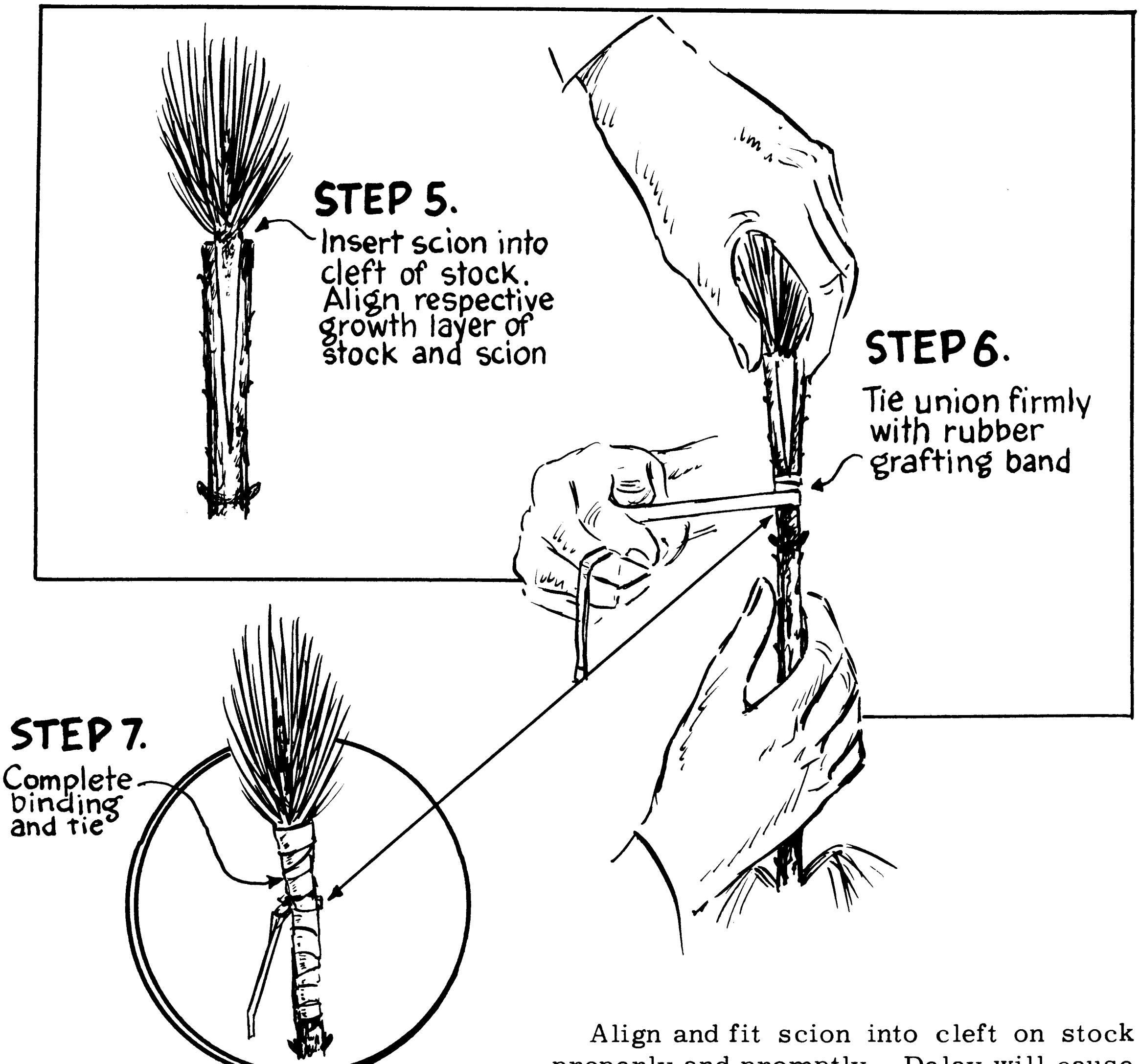


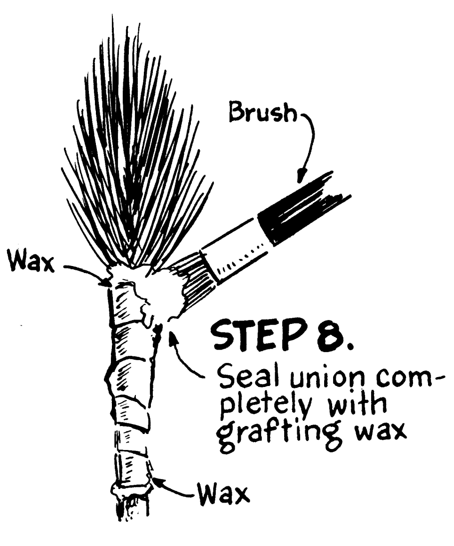
Figure 41a.—Grafting with succulent tissue (cleft graft). (Mergen and Rossoll 1954)



Collect the scions from the outer edges of the crown. Use only the succulent growth from the current year, as the scion need only be 2 to 3 inches long. Freshly collected material will be best and should be kept cool and moist until used. For field collection, a pail filled with clean water, or a plastic bag, have been found satisfactory. Prevent heating up of the scions. Do not use scions which become covered with mold.

Figure 41a.—Grafting with succulent tissue (cleft graft) (continued).

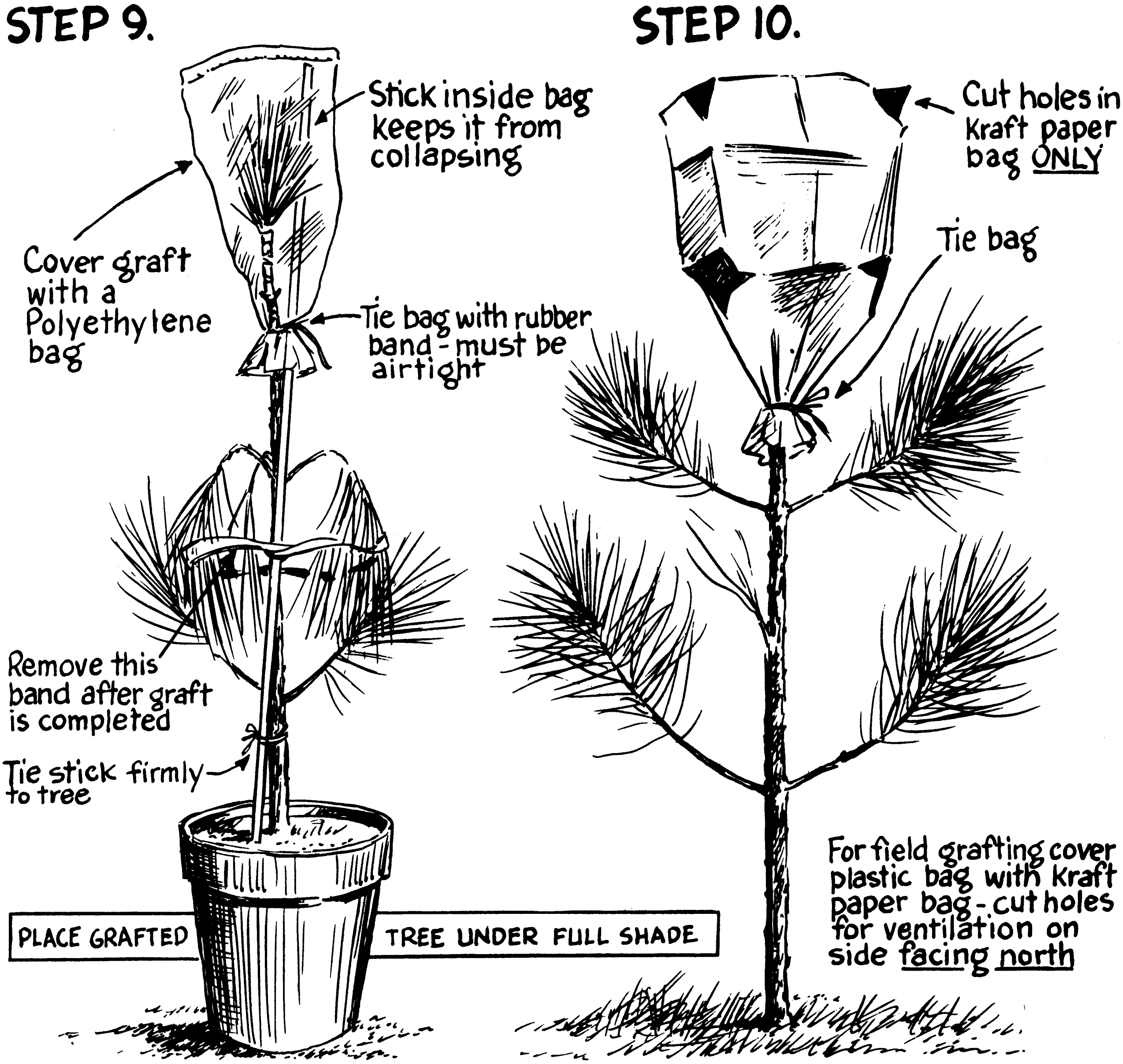




Align and fit scion into cleft on stock properly and promptly. Delay will cause desiccation of the wound surfaces, and the proper alignment decreases the distance between the graft partners which has to be bridged.

Apply the binding evenly along the full length of the union to prevent the formation of resin pockets between the cut surfaces. Also, when the contacting surfaces are uneven and not under pressure, air-filled clefts form between stock and scion. The correct binding, and the application of an even pressure along the full length of the cuts, is of great importance during the knitting of the union.

Figure 41a.—Grafting with succulent tissue (cleft graft) (continued).



Polyethylene plastic bags of various sizes can be purchased in hardware stores. They are sold as packaging material for deep-freezers.

If convenient, the new whorl of branches being formed below the graft can be enclosed also within the bag. Keep the bags over the grafts for 4 to 8 weeks, depending on the weather. Remove bags gradually by first loosening the binding of the bag and letting outside air into the bag for a couple of days. After bag has been removed completely, cut grafting rubber as indicated later.

Figure 41a.—Grafting with succulent tissue (cleft graft) (continued).

Again it is emphasized that only vigorous plants should be used as stock. When grafting dormant slash pine scions, best results are obtained with the bottle-graft method. This method has proven its value when tested in a greenhouse, in a lathhouse, under partial overhead shade in a forest, and under open field conditions in a 2-year-old plantation. The best time to graft dormant slash pine scions is during January, February, and March.

Bottle grafting is especially well suited for field grafting, because no sweat boxes are necessary for this type of graft. Direct field grafting has several distinct advantages over grafting on potted stock, namely, potted slash pines even when in fairly large pots are not as healthy as plants which have an unlimited space for root development. Also, moving potted plants from one location to another, and outplanting into the field brings about a sudden change in environment which is not without consequence. In addition, grafting directly onto stock in the field will save a great deal of preparatory work which is necessary for grafting on potted stock.

Healthy, 2- to 3-year-old slash pines make the best understock. A 1- to 2-year-old plantation on a good site is ideal for field grafting. It provides uniform stock which is spaced evenly. Before grafting begins, the plants which are to serve as understock can be freed from competing vegetation and fertilized.

Grafting can be started as soon as active growth of the stock begins. This can easily be determined by the new root activities and by the growth of the buds.

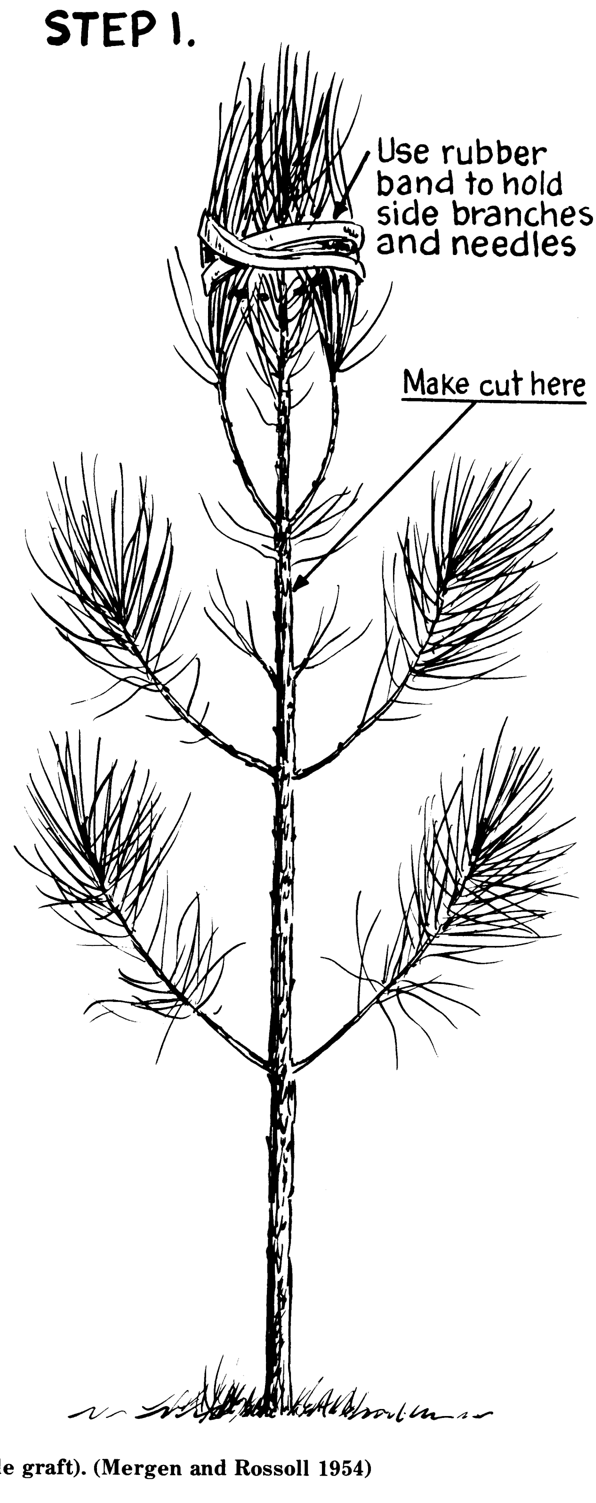
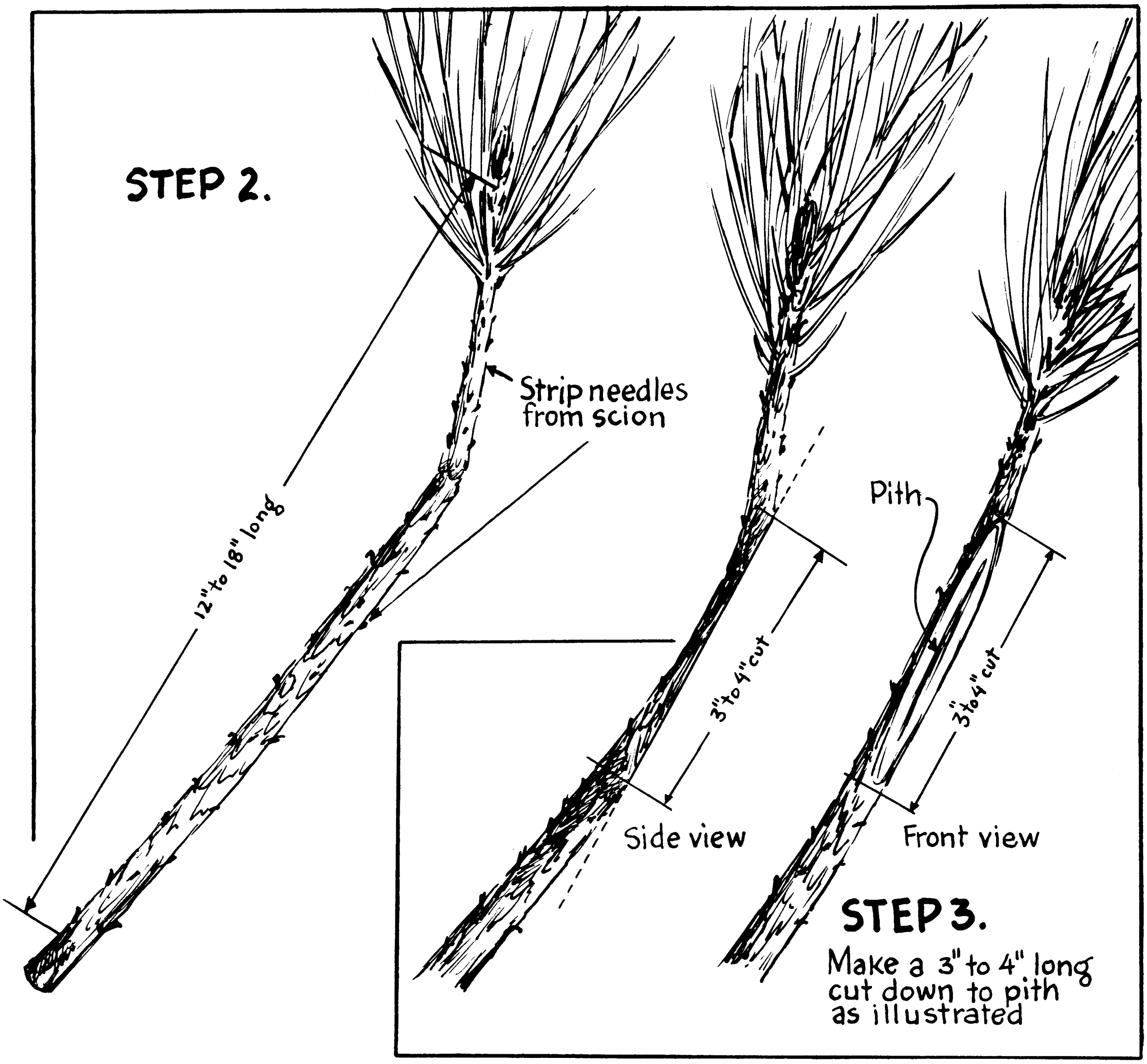


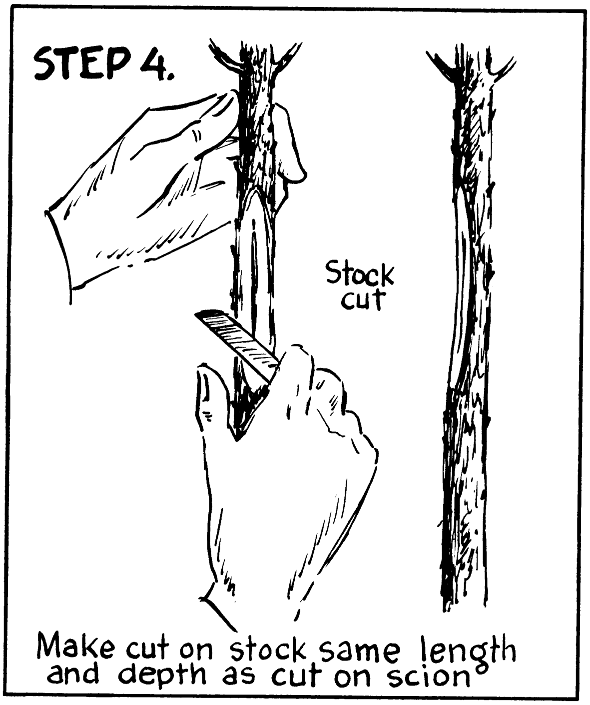
Figure 41b.—Graft with dormant scion (bottle graft). (Mergen and Rossoll 1954)



Best results will be obtained if the development of the stock is further advanced than that of the scion. For greenhouse grafting, the stock plants can be forced into active growth by gradually raising the temperature of the house. In a lathhouse, the soil temperature within the pots can be raised by thermostatically controlled lead-sheathed heating cables. For field grafting, where the start of the active growth of the stock cannot be controlled, the development of the scions can be held back by storing them in a refrigerator for a few weeks. If the development of the scion is further advanced than that of the stock, the scion will start to draw water before the stock can supply it.

Collect the scions from the outer edge of the upper half of the crowns. The distal ends of the primary branches make good scion material. Slash pines have several growth periods during one growing season. This frequently results in the formation of bends in the shoots. If possible, make grafting cut through the natural "elbow" as illustrated. Start cut some 3 to 5 inches from bud of scion.

Figure 41b.—Graft with dormant scion (bottle graft) (continued).



Select a section on the stock where the diameter is large enough to support the scion. The part of the stock on which the cut is made has to be free of overgrown wounds, insect attacks, and branch stubs. Prepare cut with a single drawing motion; this will leave a flat, smooth surface. Always keep cuts on scion and stock clean. Match stock and scion promptly to prevent drying out of the surfaces.

After binding, check alignment of stock and scion.

For grafting directly on stock in the field, place graft on the north or shaded side of the stock where the branches and needles of the plant itself will provide shade.

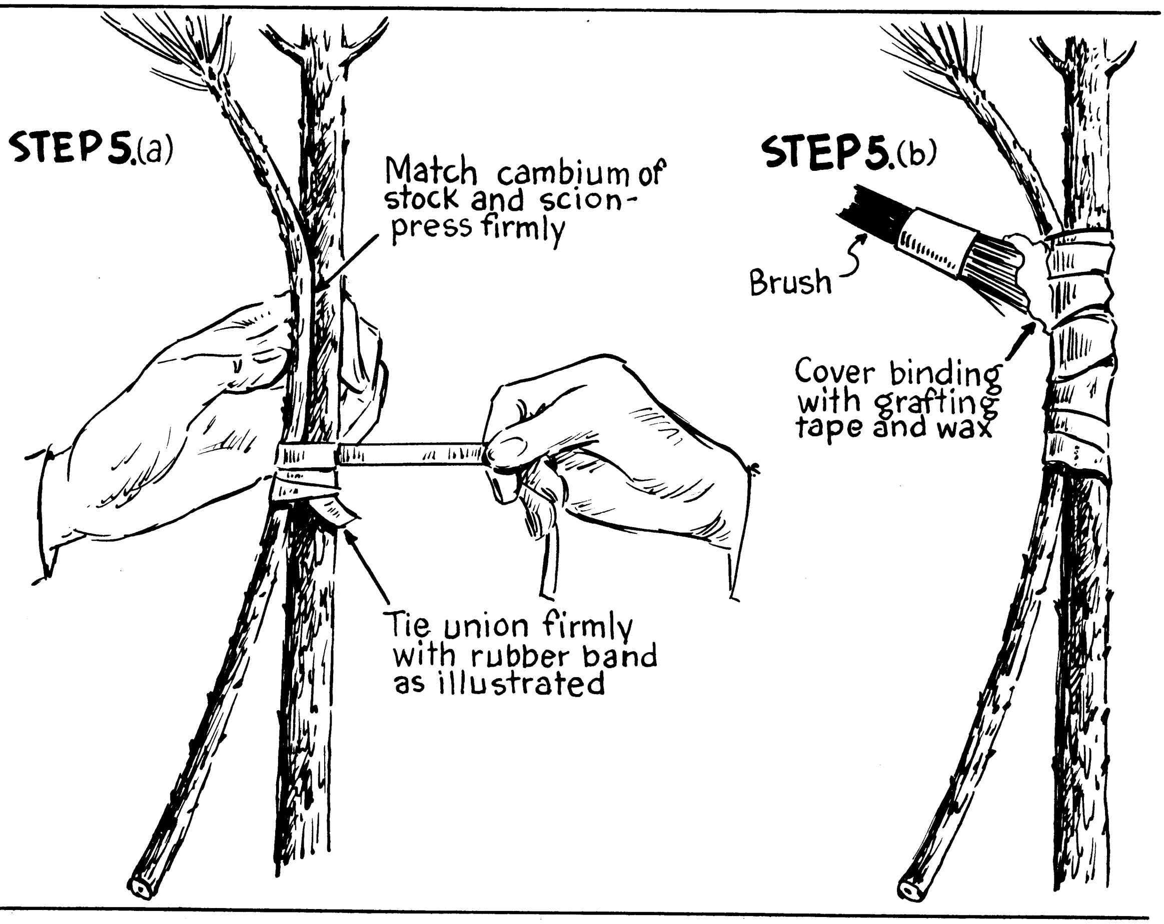
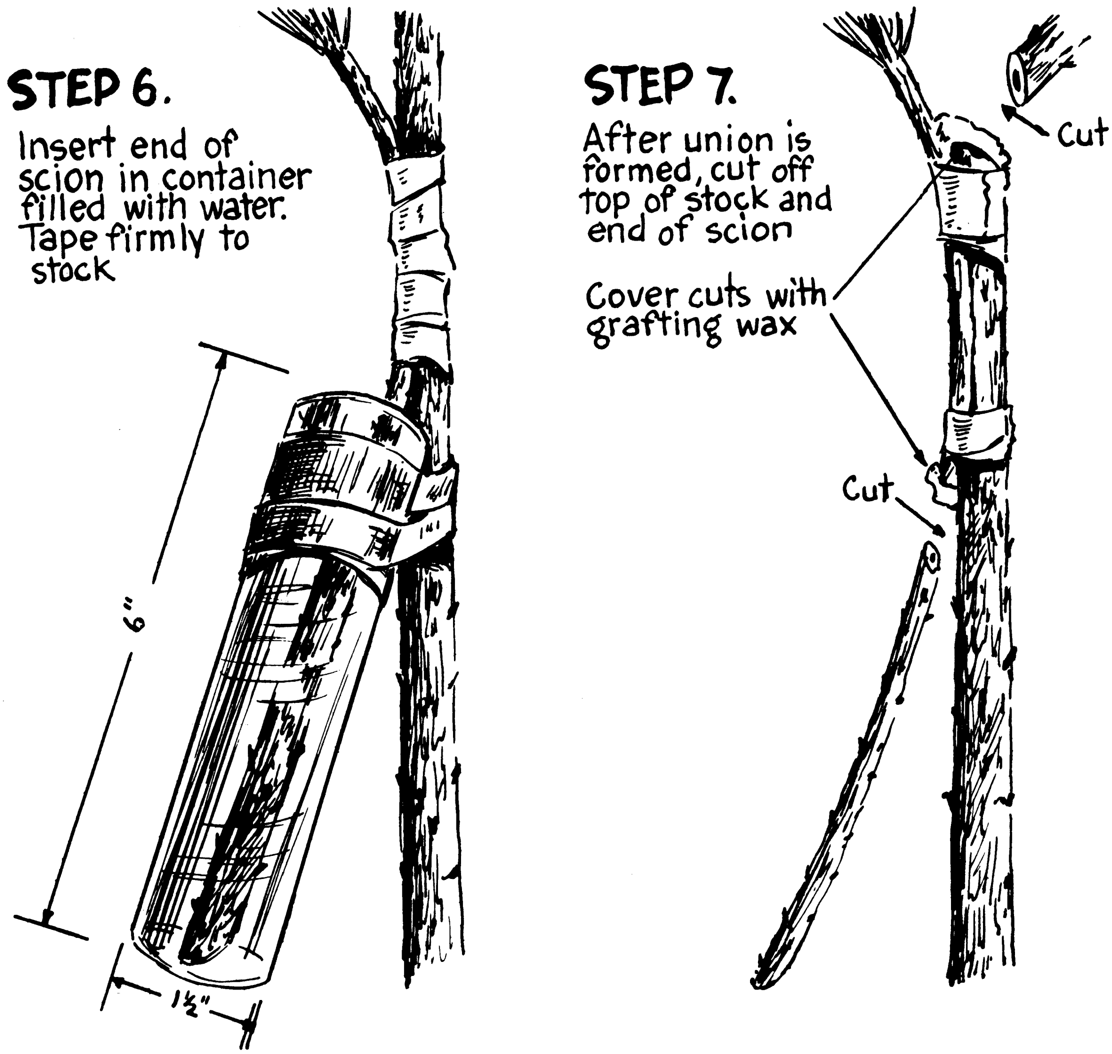


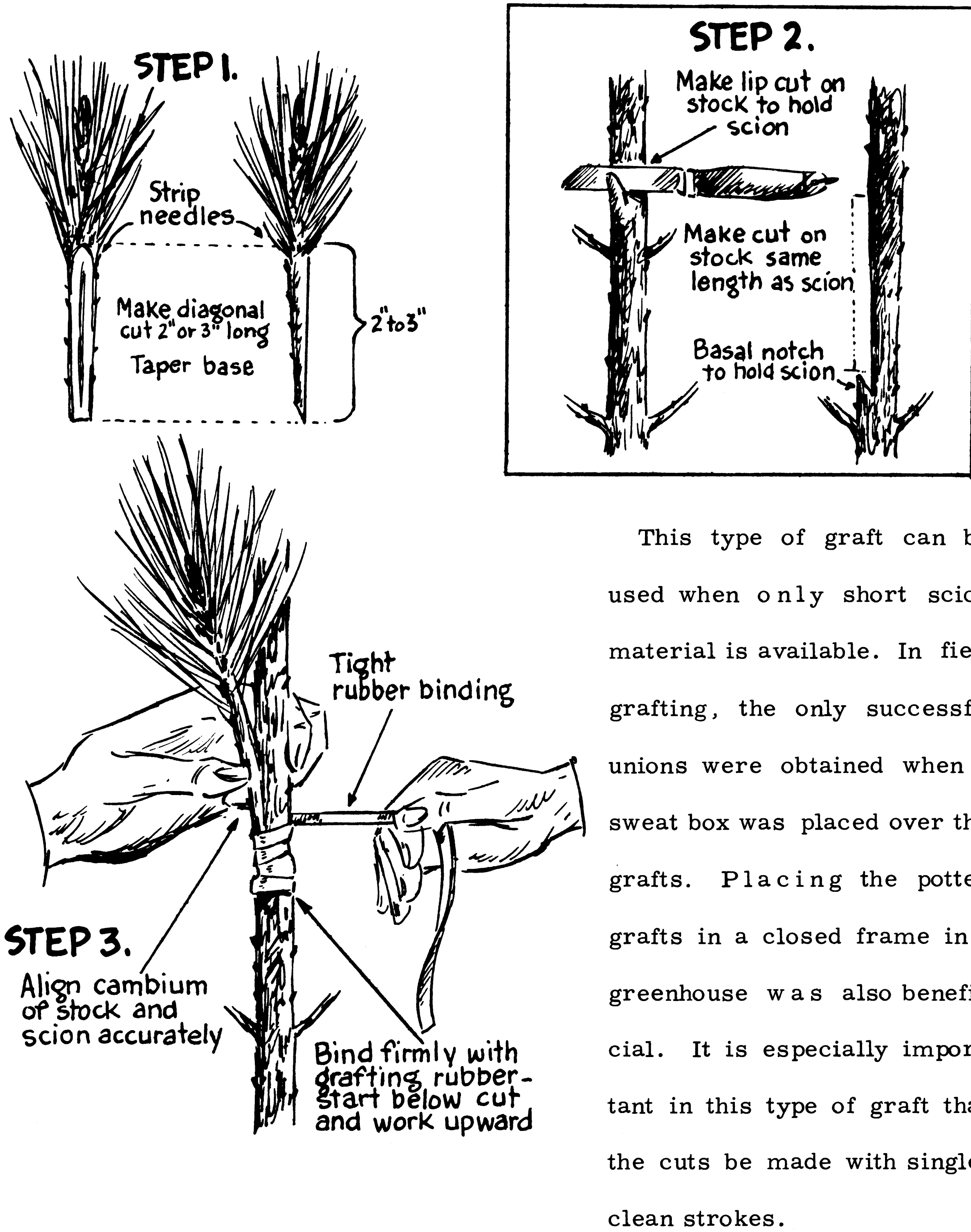
Figure 41b.—Graft with dormant scion (bottle graft) (continued).



Keep bottle filled with clean water. If bacterial or algal growth starts to clog the absorbing surface of the scion, remove bottle and wash out all dirt. Before replacing bottle, clip off about one-half inch from the base of the stock.

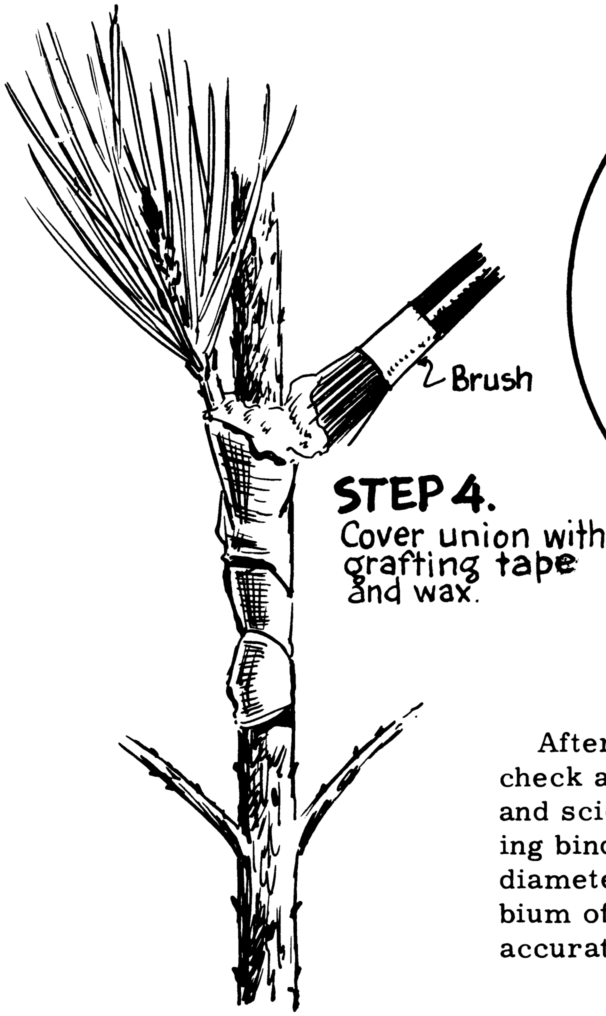
After the grafts have been made for a period of 2 to 3 weeks, the remainder of the stock branches above the union should be removed gradually. The speed of removal of the excess foliage depends upon the vigor and condition of the individual plants, but in most instances can be completed some 10 to 14 weeks after grafting. Make final cuts as illustrated to allow the grafted scion to become the leader. A loose binding with grafting tape over the newly formed union is desirable to protect it against wind breakage. Also, the grafts should be staked if additional support is needed.

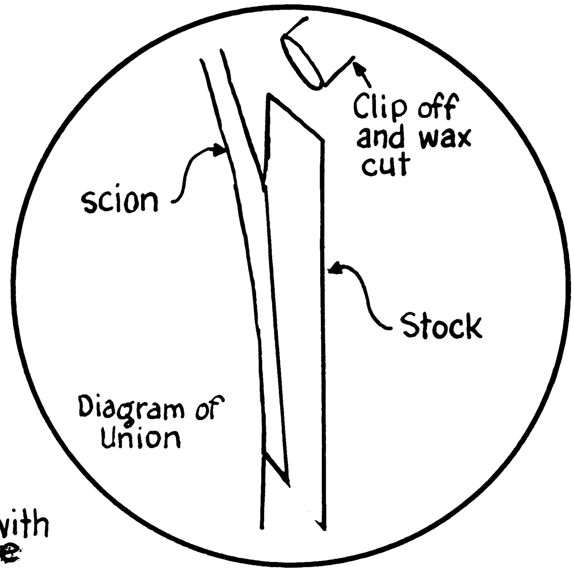
Figure 41b.—Graft with dormant scion (bottle graft) (continued).



This type of graft can be used when only short scion material is available. In field grafting, the only successful unions were obtained when a sweat box was placed over the grafts. Placing the potted grafts in a closed frame in a greenhouse was also beneficial. It is especially important in this type of graft that the cuts be made with single, clean strokes.

Figure 41c.—Veneer graft. (Mergen and Rossoll 1954)





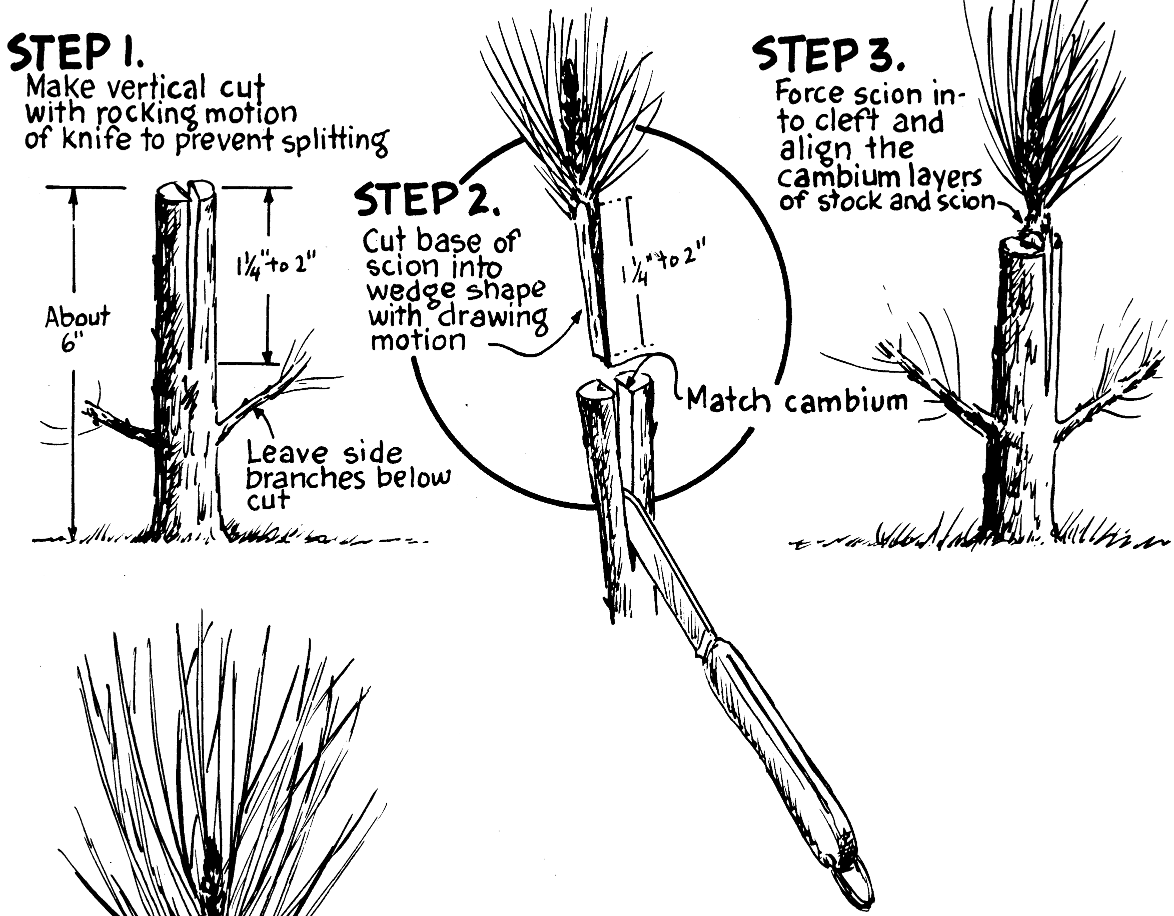
After union is bound with grafting rubbers, check alignment of the growth layers on stock and scion, as a scion slips occasionally during binding. When there is a difference in the diameter between stock and scion, the cambium of the stock and scion should be aligned accurately on one side.

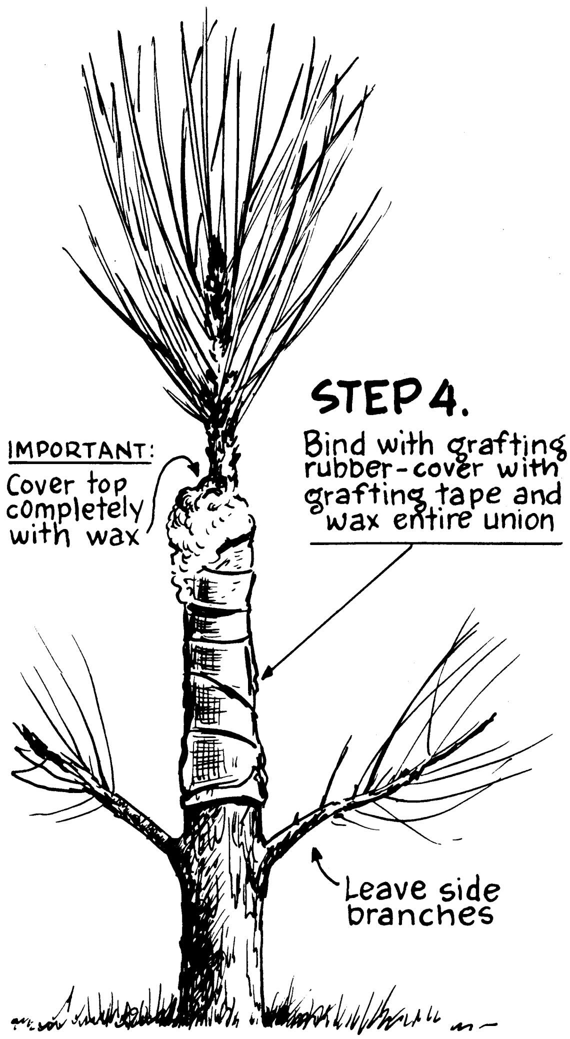
The cutting back of the stock and the rebinding of the union should follow the same pattern as described in page 13.

Clippers of the anvil type have been found best in our grafting work. Pruning shears do not leave a clean cut.

The grafting wax can be heated over a portable lamp for field grafting or on a hot plate for greenhouse and lathhouse grafting. Be careful and do not apply wax in too hot a condition. Test before using it. Most wax heating lamps have an open flame, and caution should be taken to avoid starting grass fires.

Figure 41c.—Veneer graft (continued).





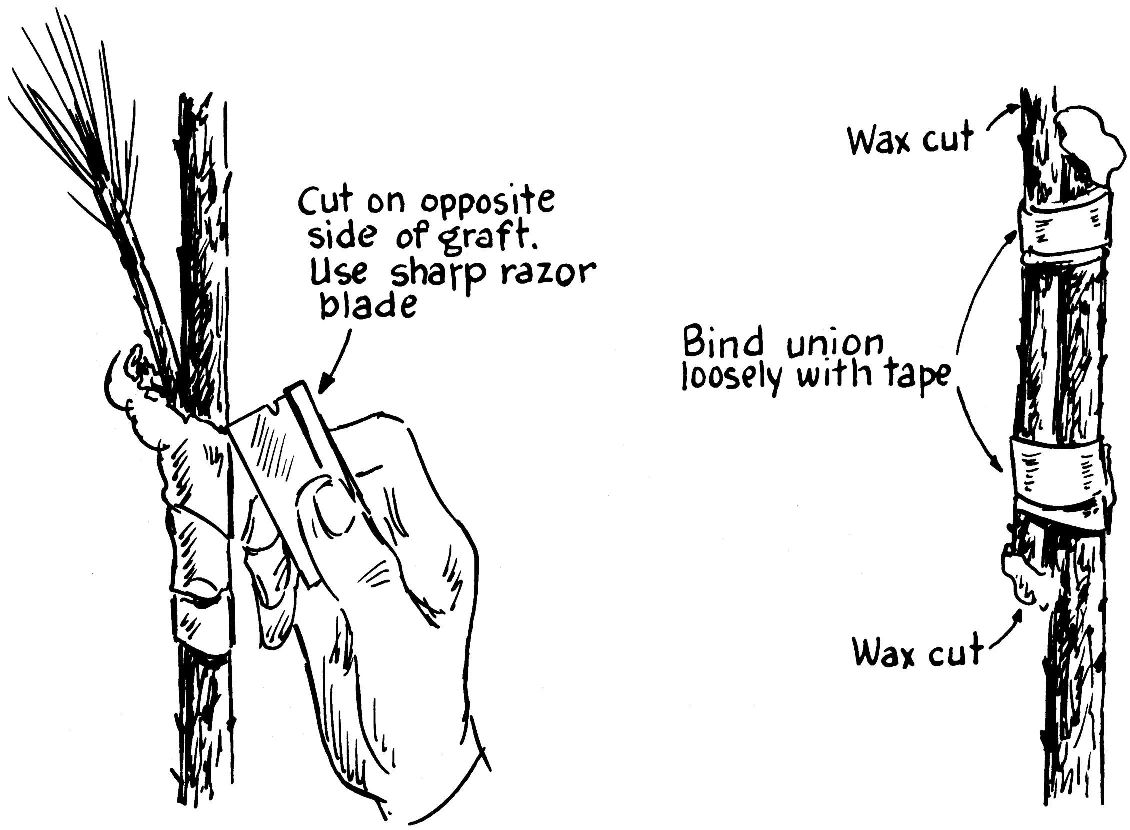
Cleft grafts with lignified stock tissue gave poor results with slash pine. This method should only be attempted in a greenhouse or under a shaded sweat box in the field.

One to several side branches with green foliage should be left below the cut surface. This green foliage will act as a pump in supplying water and nutrients from the roots of the stock to the scion.

This method, however, permits use of stock plants which are not suitable for any of the other types of grafts. Also, no further cutting back of the stock plants is necessary after the graft is made.

Cleft grafts, in general, make very strong unions.

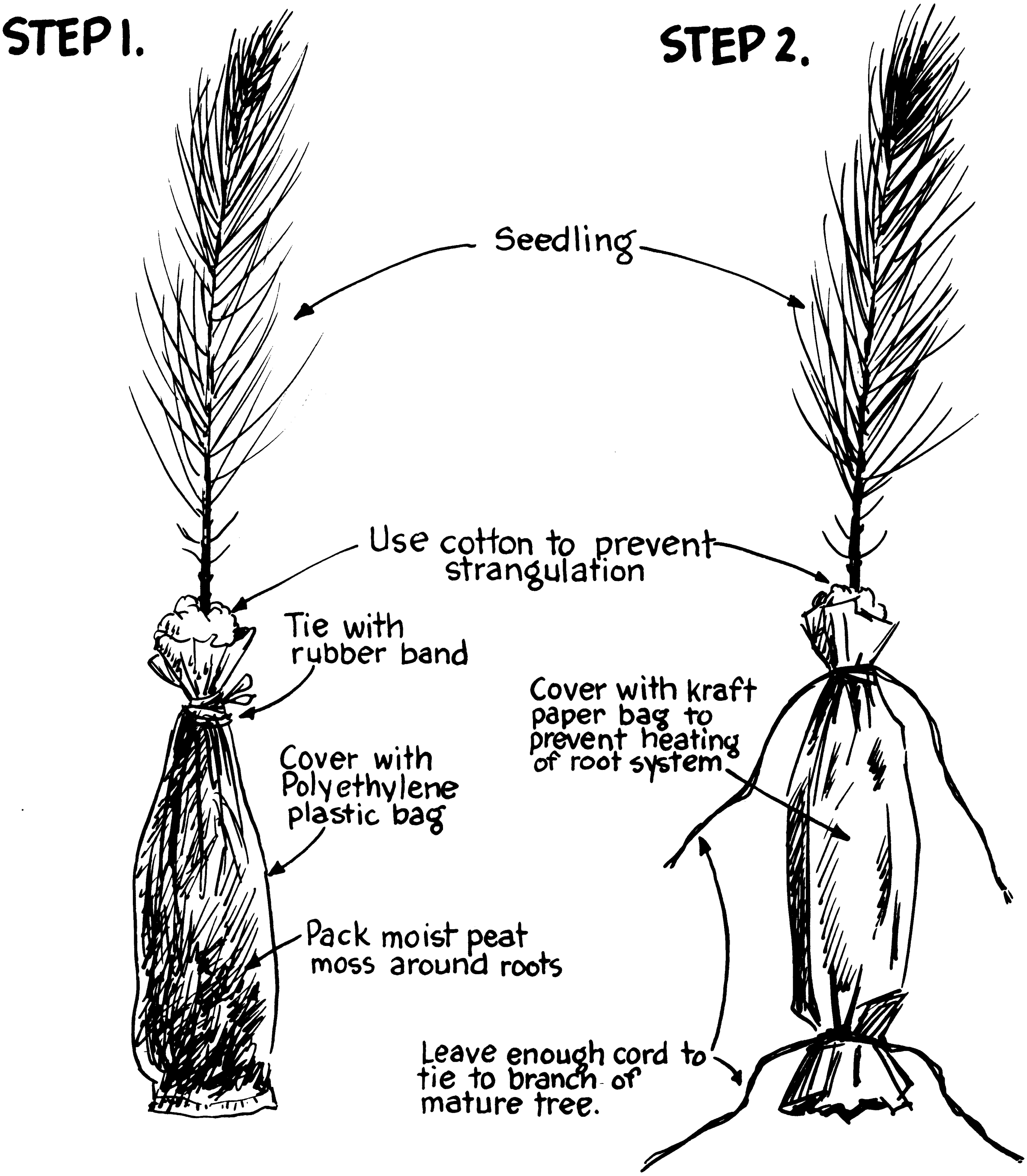
Figure 41d.—Cleft graft. (Mergen and Rossoll 1954)



The unions should be watched carefully for signs of strangulation by the binding. After the union has formed, the binding is removed by cutting it on the opposite side of the graft with a sharp razor blade as illustrated. The cutting edge should be wiped clean with alcohol frequently to remove the grafting wax.

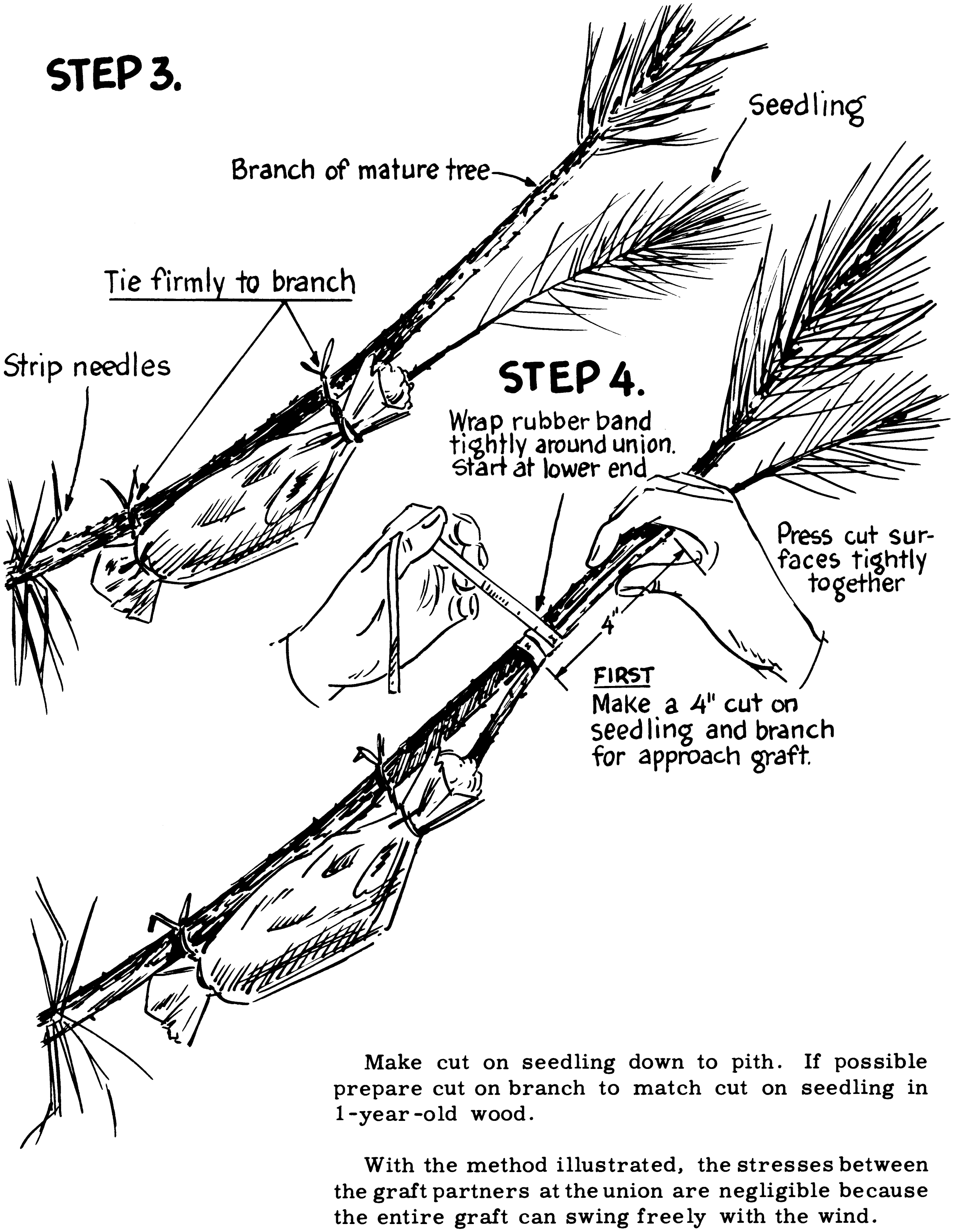
The union should be bound loosely with tape to strengthen it against wind breakage. When the final cut is made on the stock, care should be exercised to prevent the breaking loose of the newly formed callus tissue. The final cut(s) should have a slanted surface. Use very sharp clippers. Grafting wax should be applied to these cuts to prevent drying out and checking of the wound.

Figure 41e.—Removal of grafting rubber and tape after union is completed in all types of grafts. (Mergen and Rossoll 1954)



Seedlings with bare root systems have been successfully grafted into the upper and lower portions in crowns of mature slash pines. Grafting should be done during February, March, or April.

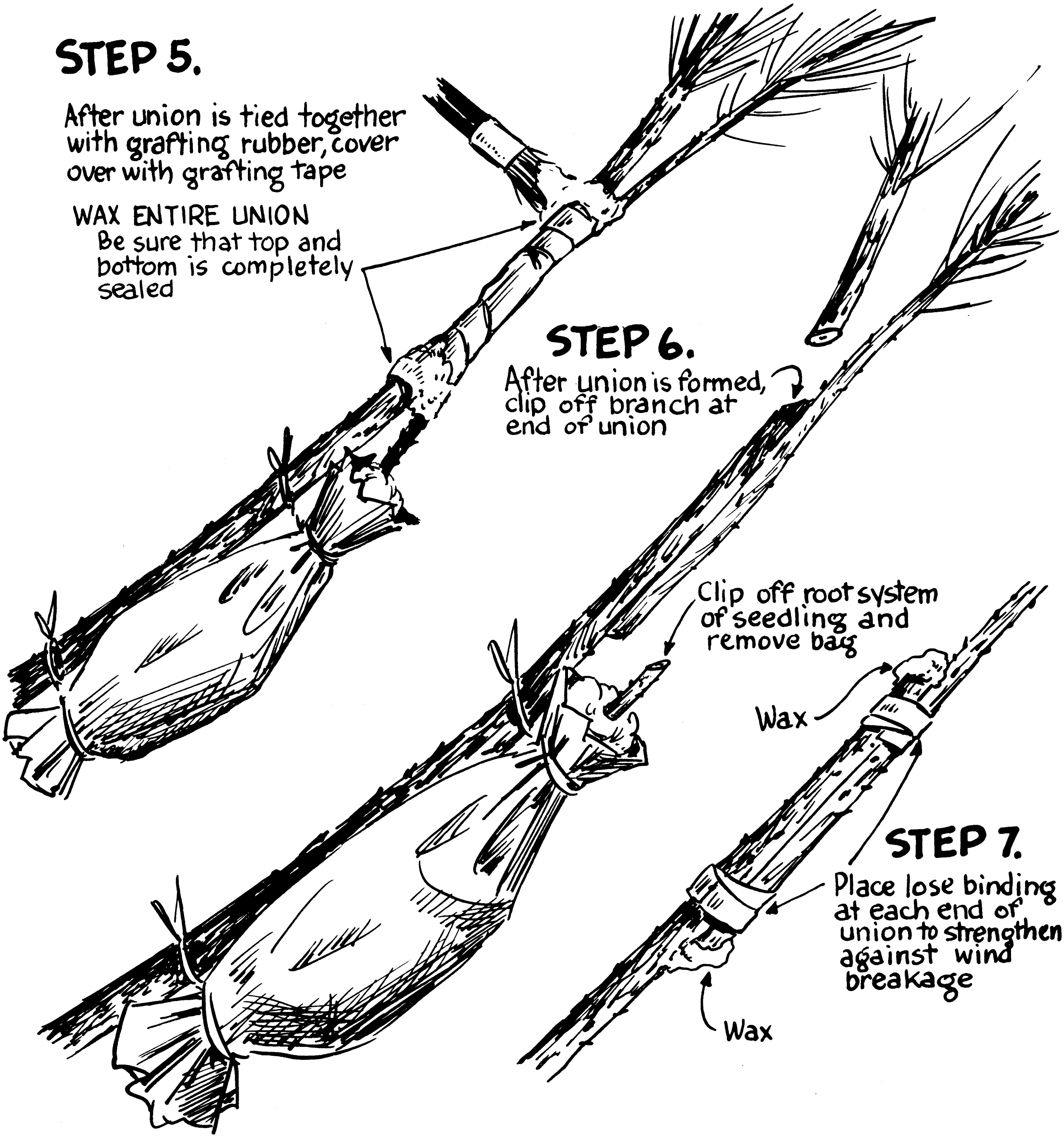
Figure 41f.—Inarching seedling into mature tree. (Mergen and Rossoll 1954)



Make cut on seedling down to pith. If possible prepare cut on branch to match cut on seedling in 1-year-old wood.

With the method illustrated, the stresses between the graft partners at the union are negligible because the entire graft can swing freely with the wind.

Figure 41f.—Inarching seedling into mature tree (continued).



The binding should be removed after 10 to 14 weeks to ensure against strangulation, using the method as illustrated on page 18. At this time the end of the branch and the root system of the seedlings are cut off.

Figure 41f.—Inarching seedling into mature tree (continued).

Photos courtesy of Georgia Forestry Commission

Figure 42.—1-0 rootstock of slash pine grown 12 by 12 inches on nursery seedbed (top). Seedbed grafts of slash pine are under shade cloth, which does not show in the photograph (middle). Grafted slash pine at 1 to 2 years are ready for transplanting in the seed orchard (bottom). (Wynens 1965)

Grafting Needle Bundles and Buds

Tests in grafting plant buds have been largely unsuccessful. It has been difficult to keep the small grafted parts in good condition until the union occurs. Small parts with buds, such as needle bundles, offer few savings in time and techniques over conventional scions.

In summary, grafting techniques have become highly perfected because of the need to produce large numbers of trees for commercial seed orchards. Careful planning and execution of jobs is required during the sequence of tasks, starting with production of stock plants to final pruning of successfully grafted little trees.

Pruning Understocks

Observations in Florida of both slash and loblolly pine grafts indicate that some healthy branches should be left on the understocks until the graft union has completely healed (Perry 1960b). During the first year, pruning should be designed to force the development of the scion, and to avoid ring knots, but some feeder branches should be left on the stock. These feeder branches can be removed after the first or second growing season in the field. This technique was developed as a result of observations showing that stock and scion did not develop evenly unless each had branches from which to obtain nourishment until the union was completely healed.

Early and rapid pruning results in graft failure. Quick removal of the stock crown after grafting causes too great a reduction in the stem diameter growth, and consequently delays and prevents the development of a sound union. Pruning, therefore, should be gradual and should always be very light. Removal of a small side branch may be sufficient. Then, as the volume of scion foliage increases, more and more of the stock crown can be removed until only that of the scion remains (Zak 1955b).

In the Cooperative Forest Genetics Research Program of the University of Florida, most of the grafted trees grew well, but in some cases the stock outgrew the scion with a characteristic flattened, milk-bottle shape. Nearly all grafts with this overgrowth died a year or so after field planting. At first, stock-scion incompatibility was suspected of causing failure of these plants. However, subsequent investigation showed that absence of healthy branches on the stock resulted in mortality of the stock and hence the scion. Evidently there is a phloem block induced as a result of the grafting operation. Whenever there was an adequate supply of food to the stock from its own branches, the stock growth was able to match the growth of the scion so that a healthy plant resulted (Perry 1960b).

Protection For Grafts

Damage to grafted slash pine stock in Florida

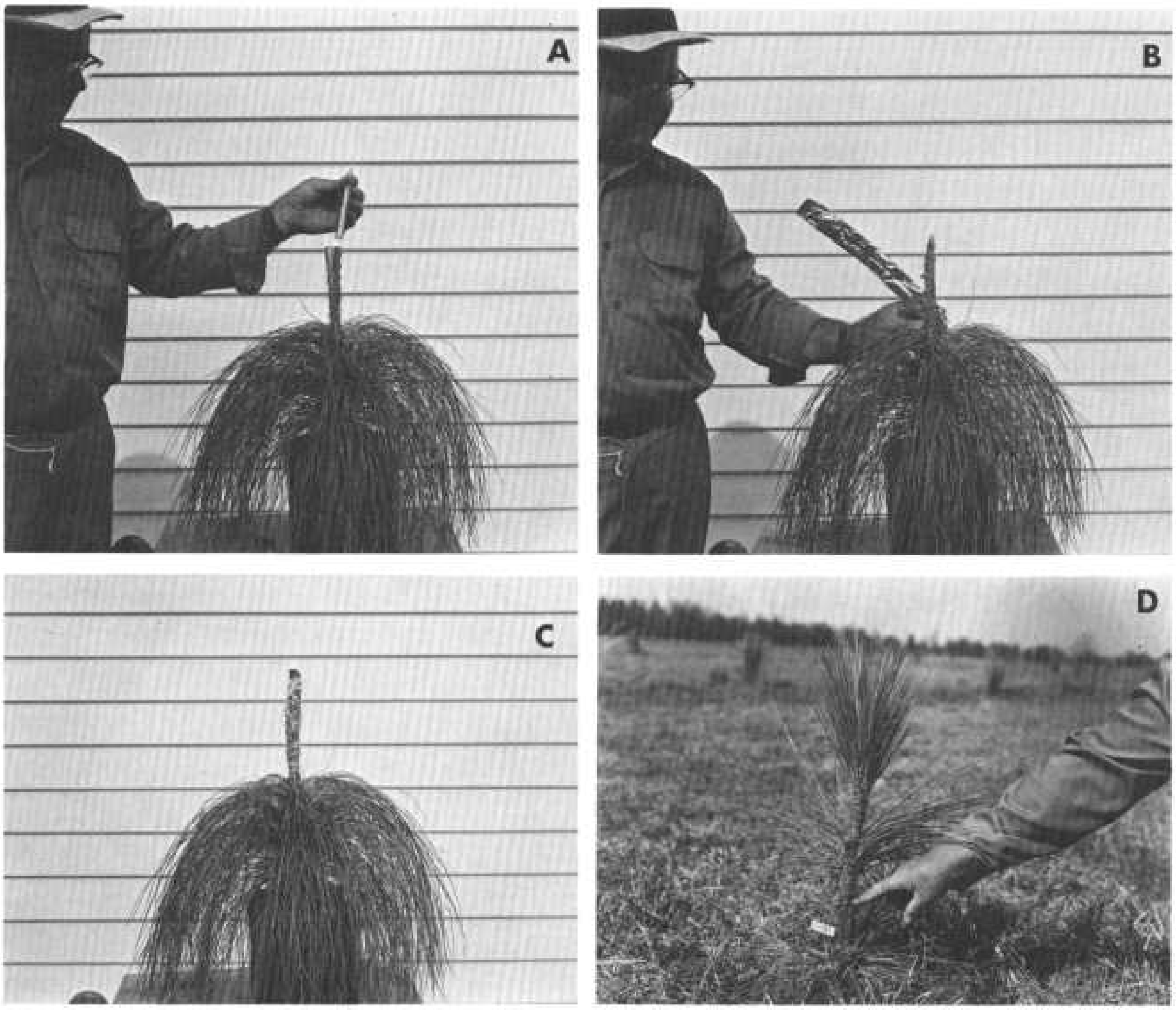


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Figure 43.—Steps in grafting longleaf pine are (A) trimming of stock and scion and (B) wrapping stock and scion. Completed graft is shown in (C) and the successful union of stock and scion is shown in (D). (Smith and Smith 1968)

was extensive as a result of an insect attack (Smith and Mergen 1954). The insect was identified as *Pityophthorus pulicarius* (Zimm.), a small bark beetle. Under normal conditions, the small bark beetle, 1.3 to 2.0 mm long, is usually content to attack the tips of newly felled or dying pines and the tips of branches which are in the process of natural pruning. In the past it has been of little importance. Fresh scions, however, apparently meeting its requirements, were attacked in the lath house with 25-percent loss and in the field replicate 10 to 12 miles away with losses of approximately 15 percent. The first sign of insect attack is the frass which the beetle pushes out as it bores into the tip. This may be easily overlooked since it is inconspicuous. The entry is quite often made at the base of the needle fascicle or through an old needle fascicle scar. More readily noticed is the dying of the old needles, usually starting at the bottom of the scion just above the union. The elongating tip remains green for some time. The scion wood at the union may remain healthy up to 3 months after the upper portion has died. Beetles, tip moths, and other insect enemies of particular species can usually be controlled with available chemicals. Important pests may vary among geographic locations, but it is advisable to provide for needed protection when seed orchard plans are prepared.

Insect and disease enemies of seed orchards are being intensively studied; hence, control measures recommended by pathologists and entomologists should be followed.

Figure 44.—Field graft of loblolly pine in the "pinfeather stage," which is considered necessary before beginning gradual removal of the protective covering over the scion. (Webb 1961)

Incompatibility of Stock and Scion

One problem that has arisen in connection with large-scale seed orchard grafting is that of incompatibility of stock and scion even though they are of the same species. This difficulty has been particularly noticeable when both slash and loblolly pines were being grafted. Graft incompatibility, long recognized as a problem in horticultural work, has been fully discussed by Mosse (1962).

The failure of the stock and scion to form a perfect union was probably first observed in southern pine grafting during research conducted by the Texas Forest Service (Cech 1958). In North Carolina, Webb (1961) recognized the possibility of stock-scion incompatibility and selected a number of parent trees for studies of grafting techniques. In a review of grafting for pine seed orchards, Otterbach (1963) received reports from various seed orchard projects showing that an average of 11 percent of clones suffer phloem blockage and 7.5 percent die as a result of graft-union incompatibility. In Georgia, definite stock-scion incompatibility was observed throughout the grafting project, but percentagewise the number of clones that could not be successfully grafted was only about 3 percent (Wynens 1965). Twenty-two percent of 770 loblolly pine clones grafted had significant numbers of incompatible ramets, based on a survey in 31 seed orchards (Lantz 1973). Results from Virginia, slash, shortleaf, and pond pine seed orchards suggested that similar incompatibility rates occurred for these species, but samples were smaller than those for loblolly pine. No relationship was found between incompatibility and the geographic location of ortets or seed orchards. Scions of loblolly pine clones vary in compatibility when grafted on rootstocks of other southern pines species, but grafting to slash pine seemed to reduce incompatibility (Schmidtling 1973).

Although scions of certain southern pines have been grafted to rootstocks of other species, the extent of incompatibility among interspecific grafts is unknown.

Graft incompatibility is a factor in southern pine breeding but not a serious one. Selection of clones to replace those lost because of incompatibility or other causes should be provided for when seed orchard plans are prepared.

Collecting and Transporting Scion Wood

Handling large numbers of scions in seed orchard grafting programs presents special problems because of the large size of twigs, the succulent condition of the twig, and the long distances they must be transported. Large trees may be climbed and branches cut so that scion wood can be collected on the ground. Techniques of shooting branches from treetops with a rifle have been described for scion collection (Beers 1957) and cone collection (McCulley 1953).

If scions are obtained from trees already established in seed orchards and then transported to nursery sites or other nearby areas where the grafting is being done, transportation problems are not so great. If cuttings have to be transported or stored, special handling is necessary to keep them viable (Perry and Wang 1957a). Cuttings should be placed in a polyethylene bag when collected. A loose mixture of dry sphagnum moss should be added to separate cuttings and permit air circulation, with a handful of moist moss in one corner of the bag to supply moisture. After the polyethylene bag is tied, 15 to 20 holes should be made with a stick to help aeration. The package of scions should be kept cool. If cuttings are transported in an icebox, needles should not become immersed in water or come in contact with ice. From 60 to 90 percent success was obtained with scions transported in this manner in Florida, and well-prepared packages of scions were stored for more than 4 months in a 30° to 40° F coldroom. Such packages should be turned over regularly to insure adequate aeration. Cuttings packed with wet sphagnum moss and placed in tightly sealed polyethylene bags were damaged by heating and died after a few hours.

Interspecific Grafts

In horticulture, grafting a scion of one species to the rootstock of another species has been used to increase growth, decrease growth, or stimulate flower production of the scions. In southern pine forestry, grafts of certain southern pines to other southern pines and other softwoods have been successful but without apparent benefit.

Slash pine scions were grafted to seedlings of loblolly pine, pitch pine, ponderosa pine, white pine, Douglas-fir, white spruce, and Norway spruce, all in their first year of growth, but none flowered during the first year following grafting (Mergen 1954c). Among grafted root-top combinations of slash pine, loblolly pine, and shortleaf pine growing under an improved environment, scions grafted on the rootstock of faster growing species averaged little or no more height growth than on their own roots (Allen 1967). Scions averaged less growth on rootstocks of slower growing species than on their own roots. Shortleaf pine is considered the slowest growing of the four major southern pines.

In Georgia, shortleaf scions of 10 clones grafted on both loblolly and shortleaf stocks did not vary in growth rate according to species used for rootstock (Greene *et al.* 1966). Shortleaf pine was grafted with a small degree of success to *Pinus mugo* and *P. halepensis*, and loblolly pine to shortleaf pine and *Pinus densiflora* by Chase and Galle (1954). Using the soft-tissue grafting method, loblolly was successfully grafted to shortleaf pine stocks, shortleaf to loblolly pine stocks, and shortleaf to Virginia pine stocks (Zak 1955b). A total of 3 grafts of 15 attempted were successful when longleaf pine scions were bottle-grafted to slash pine stocks (Johansen and Kraus 1958). Scions of three loblolly pine clones grafted to loblolly, slash, shortleaf, pond, and spruce pine rootstocks showed: scions on spruce pine roots grew more slowly but fruited earlier and survived poorly; overall performance was best on slash pine; vegetative and reproductive phenology was not influenced by rootstocks; and clones varied in graft compatibility (Schmidtling 1973). The results confirm those of an earlier study showing good scion growth on slash roots.

In Florida, scions of a shortleaf × slash pine hybrid grew very well when grafted on slash pine stocks (Kraus 1963).

All in all, results of interspecific grafting are not highly encouraging. Southern pines naturally produce seed at an early age, and thus methods for lowering age at flowering, although useful, are not critically needed. However, combinations of species that resulted in a dwarfing effect on the scion might be useful in seed orchards to keep trees short.

ROOTING CUTTINGS

Inducing scions to form their own roots has advantages over grafting for certain purposes, in that the possibility of stock-scion incompatibility is avoided and rooted plants can be tested for resistance to soil-borne pests. There are disadvantages, too, in that rooting cuttings of southern pines requires that they be removed from the tree and nourished in an artificial environment until roots are formed. For tree species difficult to root, as are southern pines, this is a major handicap in the use of the method, even for research studies requiring relatively few trees.

A successful method of rooting, although expensive, would be highly useful in determining broad-sense heritability, establishing clone banks or breeding orchards, and delineating the effects of soils, fertilization, growing space, and other environmental factors.

Scion Material

Studies in rooting have been made with twigs from various parts of the crown and from needle bundles at different stages of growth.

Rooting Cuttings

About 25 percent of southern pine cuttings can be successfully rooted, but this percentage varies widely among species, individual studies, and treatment. Success in rooting is therefore low and unpredictable. Several weeks are required for roots to form and develop sufficiently to sustain the plant when transplanted. Successful rooting requires control of air and media temperature, humidity, light, and the application of rooting chemicals. The proper combination of factors to insure high and consistent rooting percent has not been worked out. Cuttings that root may form only one or more roots, in contrast to air layers that often form many roots.

Methods of rooting have been described for loblolly pine by Grigsby (1962, 1965) and Reines and Bamping (1962); slash pine by Mitchell *et al.* (1942), Mergen (1955a), Reines and Greene (1956–57), Greene (1962a), and Slee (1967); longleaf pine by Dorman (1947b); pitch pine by Yim (1962) and Ooyama and Toyoshima (1965); Virginia pine by Snow and May (1962); shortleaf pine by Mirov (1944); and shortleaf and Table-Mountain pines by Ooyama and Toyoshima (1965).

Rooting Needle Bundles

Being small, needle bundles would be better than cuttings for certain uses but they are difficult to root. Needle bundles from trees 3 years old or younger may root with less than 10 percent success, and some of these will not make height growth. Although rooting of needle bundles from trees older than seedlings has been demonstrated, it has proved difficult to work out the proper combination of environmental factors to increase rooting success.

Methods of rooting needle bundles of loblolly, slash, shortleaf, and spruce pines have been described by Reines (1963), Mergen and Simpson (1964), Zak and McAlpine (1957), and Hare (1965).

Factors Important in Rooting

Cuttings from trees beyond the seedling stage root with difficulty; sand or some other inert material for a media seems best; fairly high soil and air temperatures are required; common chemical treatments for rooting are beneficial if the environment is suitable; cuttings collected in the fall, about November, root better than those collected in the summer; and differences among species seem small with the possible exception that shortleaf pine may be easier to root than other species.

AIR LAYERING

Air layering is a modification of the method for rooting cuttings. A band of bark on a twig is removed; the wound is treated with a rooting chemical and then covered by moss and wrapped. The twig remains on the tree and is nourished by the tree until roots are formed.

Since air layering was demonstrated by Mergen (1955a) for slash pine, techniques have been refined and tested for additional species. Techniques were illustrated by a series of sketches (fig. 45) by Mergen and Rossoll (1954). Air layering has been successful for slash pine (Hoekstra 1957b; Slee 1967), loblolly pine (Texas Forest Service 1955a; Reines and Greene 1956; Zak 1956a; McAlpine and Jackson 1959), shortleaf pine (Zak 1956a) and longleaf pine (Johansen and Kraus 1958).

Seedlings to 3 years of age may root easily, older trees less so, but in certain species over 50 percent of air layers on trees more than 20 years old have rooted. The proper concentration of rooting powder should be used and treatment of twigs started in late spring.

Zak (1956b) obtained roots on needle fascicles of shortleaf pine seedlings by loosening a small slab of wood and bark below the needles before treatment.

Slash and shortleaf pines may respond to layering better than other species. Greater success with air layering has been obtained in Florida with slash pine than elsewhere. Air-layered twigs may produce a larger number of roots than cuttings do.

Air layering has certain advantages over other methods of propagation, but it is not easy to accomplish and has not been preferred over grafting in seed orchard projects.

TOPOPHYSIS

Among scions, nongenetic differences related to the part of the crown from which they came may occur in southern pines, but the magnitude of the differences may be small. Ability of scions to root or graft does not seem to be affected by sex of flowers they bear. A low but significant correlation between height of ramet and age of ortet was found in one small study in slash pine (Franklin 1969c). On a basis of ocular estimates, the growth of grafted clones, rooted cuttings, and air layers has been comparable to that of seedlings. In seed orchard projects, scion wood is collected throughout the crown.

DISCUSSION OF VEGETATIVE PROPAGATION

Methods of propagating southern pines by grafting, rooting cuttings, and air layers have been intensively studied and are in use. Vegetative reproduction by stimulating growth of sexual parts such as pollen has not been perfected.

Trees for clonal seed orchards have been propagated by field or nursery bed grafting because other methods are less reliable. Successful grafting requires vigorous stocks and accurate placement of scion wood. Grafted scions require protection from drying. Aluminum wrappers are widely used and are removed in stages as growth of the union progresses.

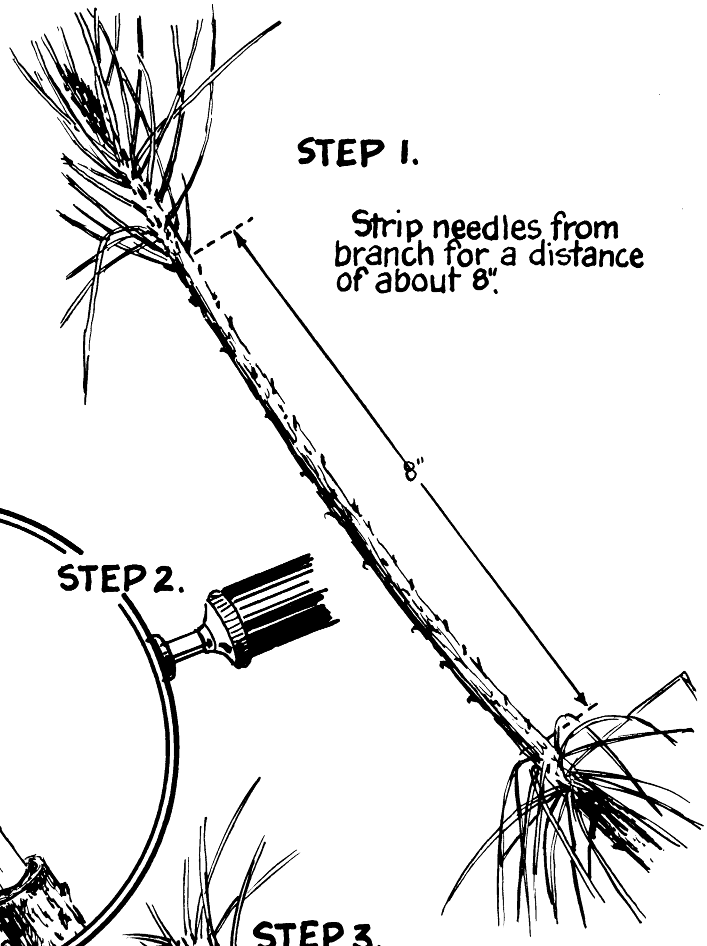
Scions from certain trees graft with poor success because of incompatibility with the stock; such trees are often rejected for seed orchard use.

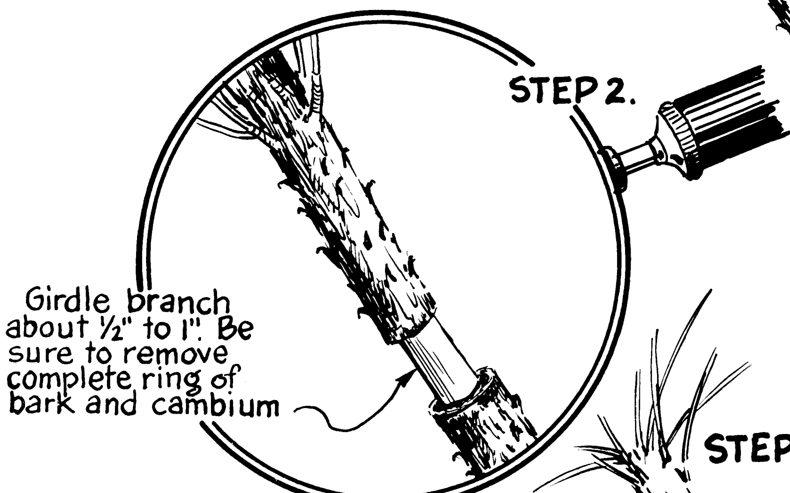
Efforts to improve growth and seed production of the scion by grafting to stock of a different species have been unsuccessful.

Source of scions throughout the crown of ortets is not an important factor in grafting.

An easier, more reliable method of producing own-rooted plants such as cuttings or air layers would greatly facilitate studies in genetical and physiological variation requiring genetically uniform trees.

The best time of year to apply the air-layers is during May, June, and July. Select sturdy, vigorous, straight shoots in the upper part of the crown. Prepare the girdle some 10 inches from the tip of the branch, preferably on the current year's growth.

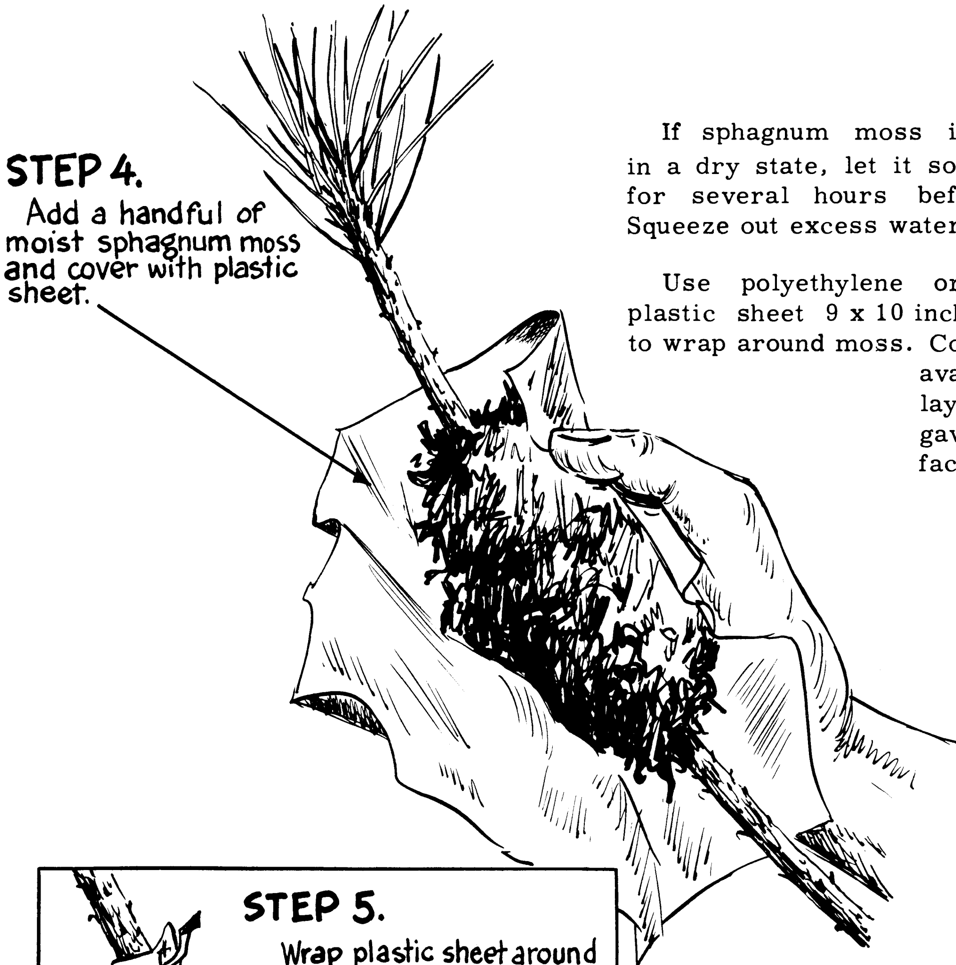




On very vigorous shoots of trees below 10 years of age use 1-inch girdle, and on older trees use $\frac{1}{2}$-inch girdle.

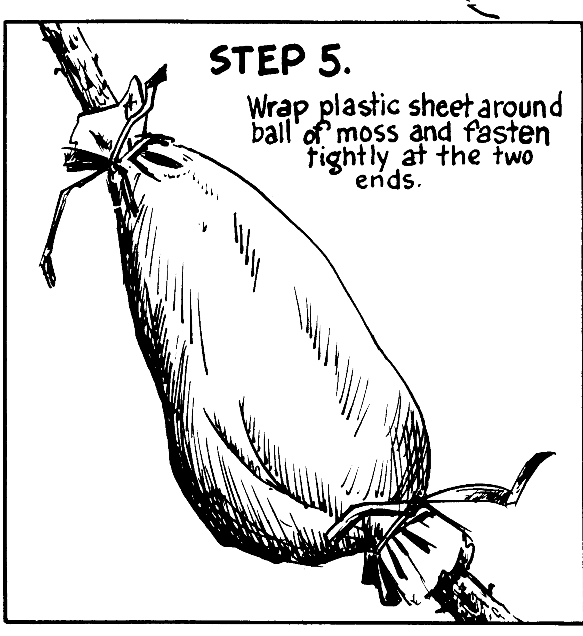
Use a 1.2-percent mixture of indolebutyric acid in talcum powder as a rooting powder. This stimulates the formation of well-balanced root systems.

Figure 45.—Air layering. (Mergen and Rossoll 1954)



If sphagnum moss is collected in a dry state, let it soak in water for several hours before using. Squeeze out excess water.

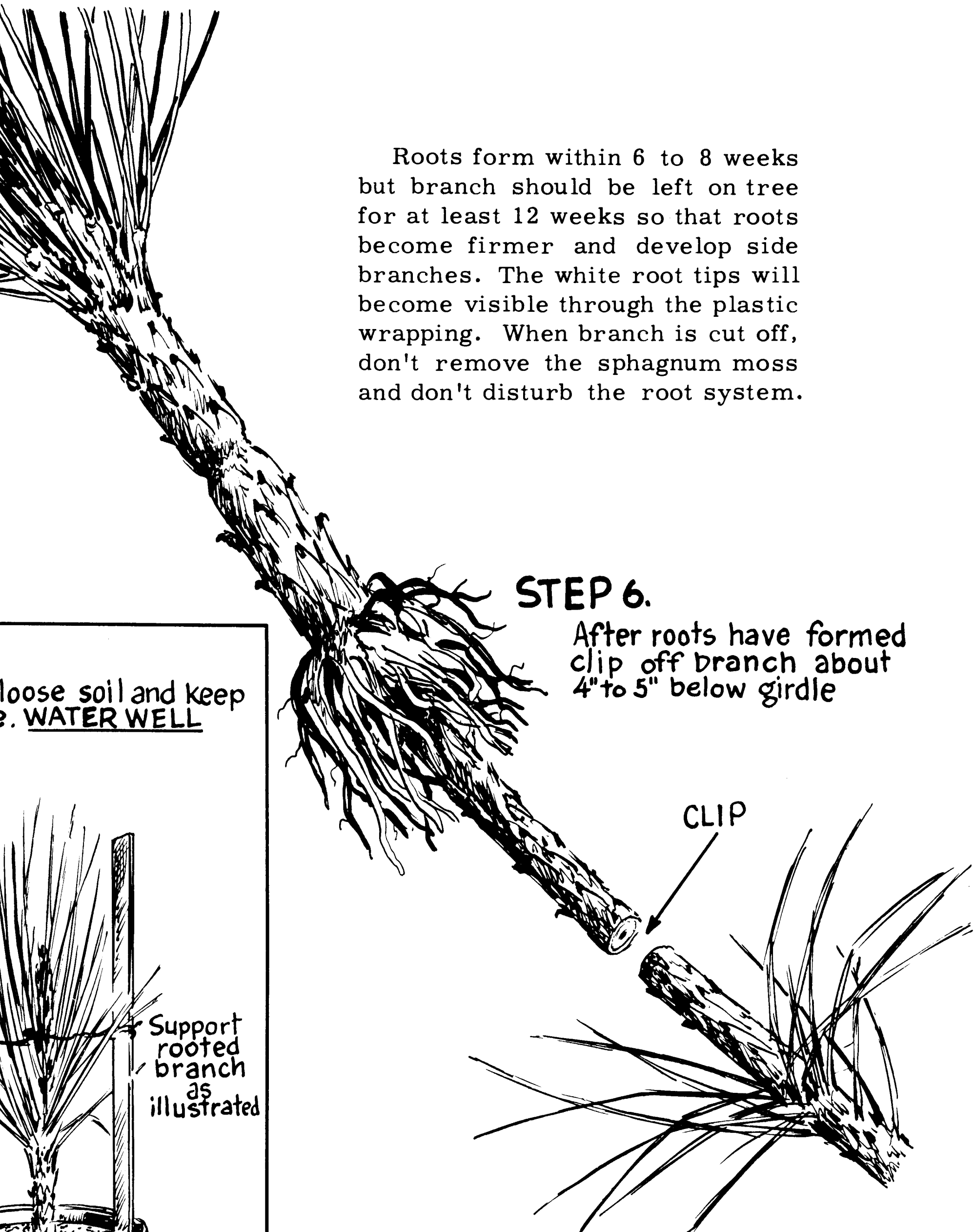
Use polyethylene or polyvinyl plastic sheet 9 x 10 inches in size to wrap around moss. Commercially available air-layering sheets gave very satisfactory results.

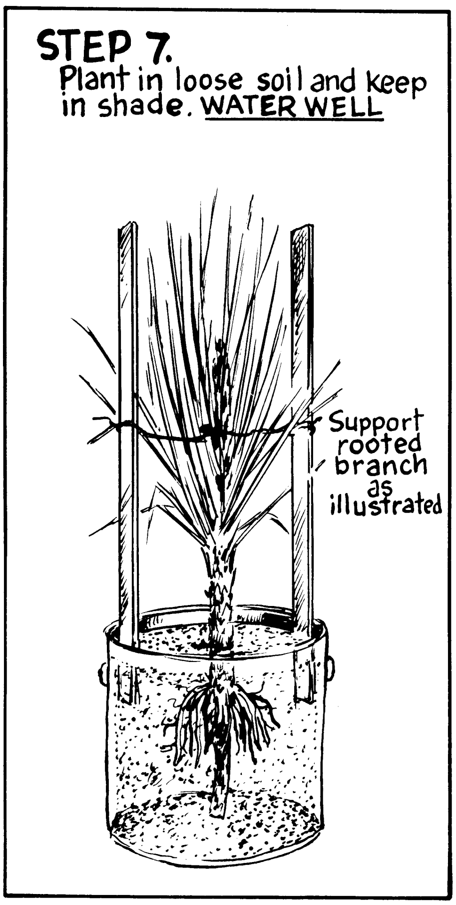


Cover the sphagnum moss completely and be sure that no opening is left for the evaporation of moisture from the moss. If properly applied, the moss will stay moist for several months. When drying becomes noticeable, add water with a hypodermic syringe.

Figure 45.—Air layering (continued).

Roots form within 6 to 8 weeks but branch should be left on tree for at least 12 weeks so that roots become firmer and develop side branches. The white root tips will become visible through the plastic wrapping. When branch is cut off, don't remove the sphagnum moss and don't disturb the root system.





A mixture of sand, vermiculite, and peat in equal parts was found very suitable as a potting medium. Fertilizing the rooted branch with a soluble fertilizer stimulates root growth. Potted plants can be outplanted into the field after roots are well developed.

Figure 45.—Air layering (continued).