

* 12

Techniques of Grafting

learning objectives

- Explain the requirements for successful graftage.
- Describe the techniques of detached scion graftage, approach graftage, and repair graftage.
- Discuss the preparation for grafting—tools, accessories, machines, automation, and processing scionwood.
- Explain the craftsmanship of grafting—manual techniques, record keeping, and mechanization.
- Describe the aftercare of grafted plants—in bench grafting systems, and field and nursery grafting systems.
- Identify field, bench, and miscellaneous grafting systems.

INTRODUCTION

Since people first learned to graft plants, a myriad of grafting techniques have been developed. In *The Grafter's Handbook*, Garner (19) enumerates and describes some forty different grafts.

Here we describe the most important grafting methods. Among them, a person who can use a sharp knife can find one that meets any specific grafting need. However, success in grafting depends not only on a technically correct graft but in preparation of the scion and rootstock for graftage. Equally critical are the optimum time for grafting, and proper aftercare.

With high labor costs, only a few of the more efficient grafts are utilized in United States woody ornamental nurseries, including the side veneer, splice (whip graft), and whip-and-tongue graft; use of approach and repair graftage is limited. With fruit crops, depending on the species, a number of different apical, side, and root grafts are utilized around the world. Chip budding and T-budding, which are described in detail in Chapter 13, are two of the most common budding methods for woody ornamentals and fruit crops. Vegetable grafting has increased dramatically worldwide—and is commonly done in Asia and Europe where land is intensively used and crops are not rotated. Grafting onto rootstock resistant to soil pathogens and environmental stress helps increase yield and reduce chemical usage (12, 21, 34). For example, some of the most important grafts with cucurbit vegetables (melon, squash) include hole insertion grafting, tongued approach, and one cotyledon graft (also known as the splice, slant, or the Japanese tube graft), which are described in the chapter. Some robotic vegetable grafting machines can produce 800 grafts per hour.

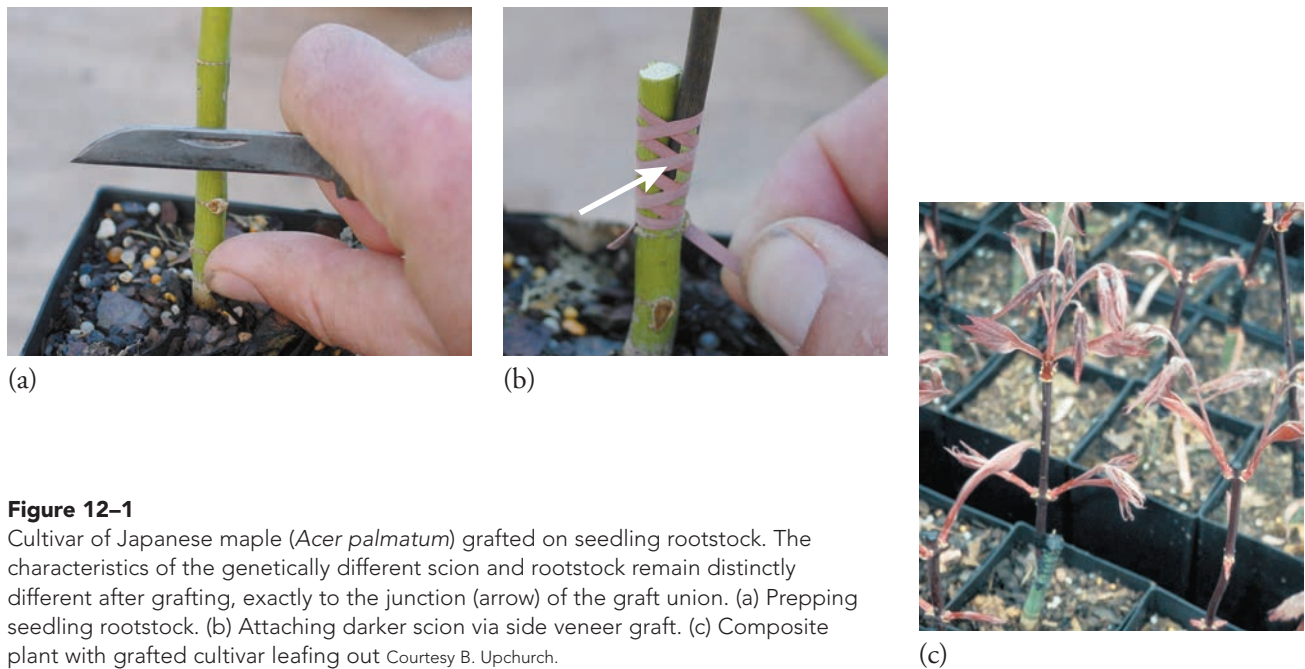
This chapter is divided into three sections: (a) the **types of grafts**, (b) **production processes of graftage**—including the preparation, craftsmanship, and aftercare of grafted plants, and (c) **grafting systems**, including field grafting, bench grafting, and miscellaneous grafting systems—such as herbaceous graftage, cutting grafts, and micrografting.

REQUIREMENTS FOR SUCCESSFUL GRAFTING

For any successful grafting operation, producing a plant, as shown in Figure 12–1, requires five important elements:

1. *The rootstock and scion must be compatible.* They must be capable of uniting. Usually, but not always, closely related plants, such as two apple cultivars, can be grafted together. Distantly related plants, such as oak and apple, cannot make a successful graft combination (see Chapter 11 for a discussion of these factors).



**Figure 12-1**

Cultivar of Japanese maple (*Acer palmatum*) grafted on seedling rootstock. The characteristics of the genetically different scion and rootstock remain distinctly different after grafting, exactly to the junction (arrow) of the graft union. (a) Prepping seedling rootstock. (b) Attaching darker scion via side veneer graft. (c) Composite plant with grafted cultivar leafing out. Courtesy B. Upchurch.

2. The **vascular cambium** of the scion must be placed in direct contact with that of the rootstock. The cut surfaces should be held together tightly by wrapping, nailing, wedging, or some similar method. Rapid development of the graft union is necessary so that the scion may be supplied with water and nutrients from the rootstock by the time the buds start to open.
3. The grafting operation must be done at a time when the rootstock and scion are in the proper physiological stage. Usually, this means that the scion buds are dormant while at the same time, the cut tissues at the graft union are capable of producing the callus tissue necessary for healing of the graft. For deciduous plants, dormant scionwood is collected during the winter and kept inactive by storing at low temperatures. The rootstock plant may be dormant or in active growth, depending upon the grafting method used.
4. Immediately after the grafting operation is completed, all cut surfaces must be protected from desiccation. The graft union is covered with tape, grafting wax, Parafilm tape, Buddy Tape, or the grafts are placed in moist material or a covered grafting frame.
5. Proper care must be given to the grafts for a period of time after grafting. Shoots (suckers) coming from the rootstock below the graft will often

vascular cambium

The tissue responsible for the formation of new xylem and phloem in the development of a successful graft union.

choke out the desired growth from the scion. In some cases, shoots from the scion will grow so vigorously that they break off unless staked and tied or cut back.

TYPES OF GRAFTS

Grafting may be classified according to the part of the rootstock on which the scion is placed—a root, or various places in the top of the plant. Types of grafts can be categorized as (1)

detached scion graftage, which includes apical, side, bark, and root graftage; (2) **approach graftage**, where the root system of the scion and the shoot system of the rootstock are not removed until after successful graft union formation occurs; and (3) **repair graftage of established trees**. The grafts that are categorized in Tables 12-1 and 12-2 are described in greater detail later in the chapter.

detached scion graftage

A type of graft used when a section of the shoot of the scion is removed and grafted to the apex or side of the rootstock. It is also used in grafting roots (**root graftage**).

approach graftage The root system of the scion and shoot system of the rootstock are not removed until after successful graft union formation occurs.

repair graftage Graft used in repairing or reinforcing injured or weak trees.



Table 12-1
TYPES OF GRAFTS

- I. **Detached Scion Graftage**
 - A. **Apical Graftage**
 - Whip-and-tongue graft
 - Splice graft (whip graft; with vegetables—One cotyledon graft [OCG] or Japanese tube graft)
 - Cleft graft (split graft)
 - Wedge graft (saw-kerf graft)
 - Saddle graft
 - Four-flap graft (banana graft)
 - Hole Insertion Graft (HIG) or Terminal/Tip Insertion graft with vegetables
 - B. **Side Graftage**
 - Side-stub graft
 - Side-tongue graft
 - Side-veneer graft
 - Side insertion graft (SIG) with vegetables
 - C. **Bark Graftage**
 - Bark graft (rind graft)
 - Inlay bark graft
 - D. **Root Graftage**
 - Whole-root and piece-root grafting
 - Nurse-root grafting
- II. **Approach Graftage**
 - Spliced approach graft
 - Tongued approach graft (TAG)
 - Inlay approach graft
- III. **Repair Graft**
 - Inarching
 - Bridge graft
 - Bracing

Table 12-2
UTILIZATION AND ROOTSTOCK CRITERIA OF SELECTED GRAFTS

Graft type	Diameter of rootstock	Rootstock condition	Uses
Whip-and-tongue graft	Small: 6 to 13 mm (1/4 to 1/2 in); same diameter as scions	Dormant; however, active with bench grafting of container rootstock	Bench grafting; container grafting; some topworking in field; root grafting; a popular graft
Whip graft (splice graft)—also called One cotyledon graft (OCG) or Japanese tube graft with vegetables.	Small: 6 to 13 mm (1/4 to 1/2 in); same diameter as scions; See Figure 12-46 for schedule.	Dormant; however, active with bench grafting of container rootstock, greenwood grafting, and vegetable crops	Bench grafting; container grafting; some topworking in field; grafting of vegetable liner plants; root grafting; a popular graft
Cleft graft (split graft)	Moderate: 2.5 to 10 cm (1 to 4 in)	Dormant—before active growth starts in spring	Topworking in field
Wedge graft (saw-kerf graft)	Moderate: 2.5 to 10 cm (1 to 4 in)	Dormant—before active growth starts in spring	Topworking in field
Saddle graft	Small: 6 to 19 mm (1/4 to 3/4 in); same diameter as scion	Dormant	Bench grafting via hand or machine; container grafting; root grafting
Four-flap graft (banana graft)	Small: up to 2.5 cm (1 in); same diameter as scions	Active; bark must be slipping	Topworking small caliper trees
Hole insertion graft (HIG) or Terminal/Top insertion graft			Bench grafting; container grafting of liner vegetable plants

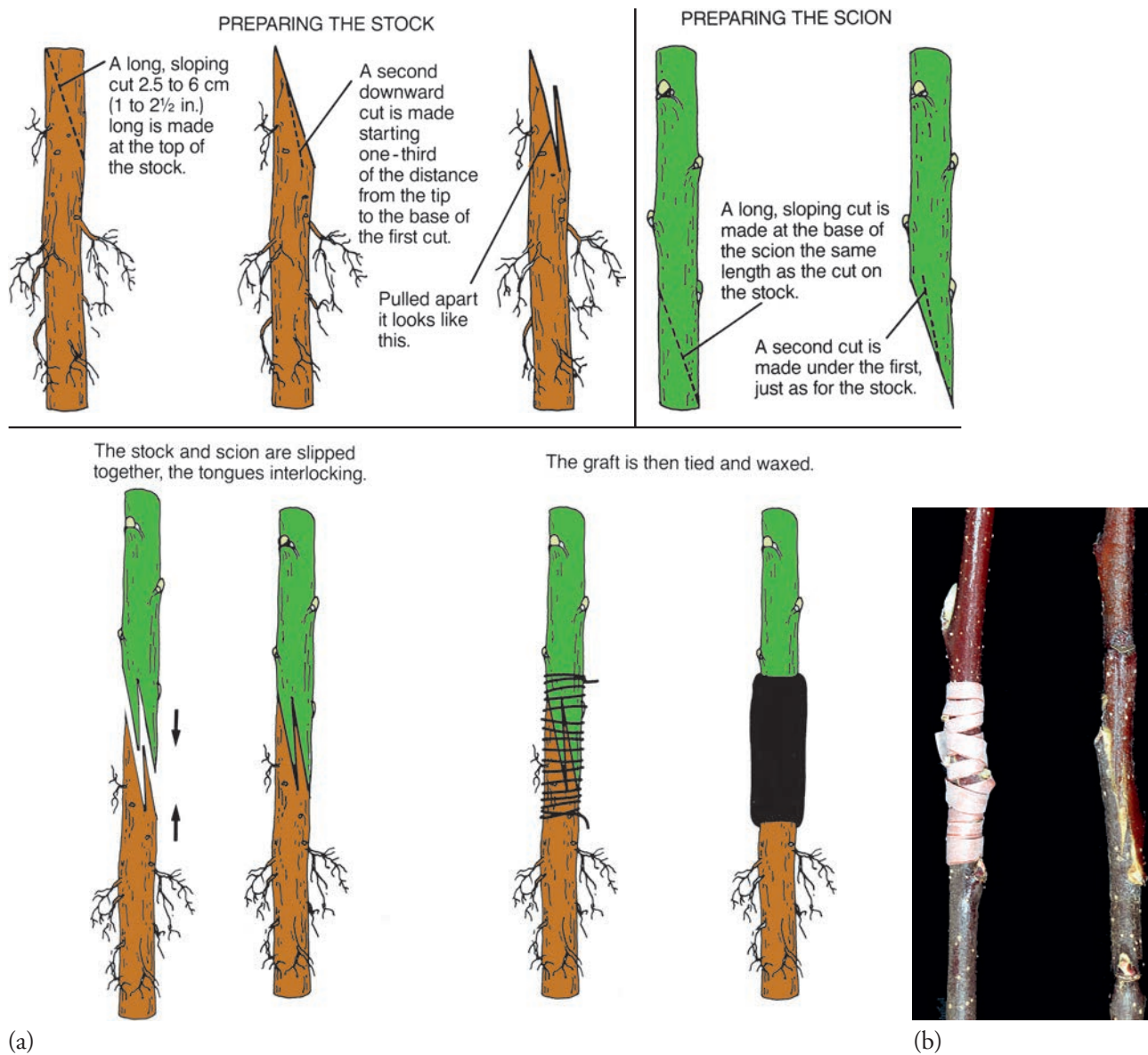


Graft type	Diameter of rootstock	Rootstock condition	Uses
Side-stub graft	Small to moderate rootstock larger than scion: grafted on rootstock branches up to 2.5 cm (1 in) in diameter	Dormant	Topworking in field
Side-tongue graft	Small: 6 to 19 mm (1/4 to 3/4 in); diameter of scion slightly smaller than rootstock	Dormant	Bench grafting; container grafting of broad- and narrow-leaved evergreen species
Side-veneer graft	Small: 6 to 19 mm (1/4 to 3/4 in); same diameter as scion	Dormant	Bench grafting; container grafting of smaller liner potted plants; a popular graft for conifers, deciduous trees and shrubs, and fruit crops
Side insertion graft (SIG)	Works well using vegetable rootstock with wide hypocotyls.	Active	Bench grafting; container grafting of liner vegetable plants
Bark graft (rind graft)	Large: 2.5 to 30 cm (1 to 12 in).	Active; bark must be slipping	Topworking in field
Inlay bark graft	Large: 2.5 to 30 cm (1 to 12 in).	Active; bark must be slipping	Topworking in field (e.g., pecans)
Spliced approach graft	Small: 6 to 19 mm (1/4 to 3/4 in); same size as scion; exception is mango grafting in India on larger, established trees	Active	Container grafting with difficult-to-graft species; scion and stock grafted as two independent, self-sustaining plants; only limited topworking in field
Tongued approach graft (TAG)	Small: 6 to 19 mm (1/4 to 3/4 in); same size as scion	Active	Container grafting with difficult-to-graft species; scion and stock grafted as two independent, self-sustaining plants; also used with vegetables
Inlay approach graft	Small: 6 to 19 mm (1/4 to 3/4 in); bark of rootstock is thicker than scion	Active	Container grafting with difficult-to-graft species; scion and stock grafted as two independent, self-sustaining plants
Inarching	Large: 15 cm (6 in) and larger	Dormant	Used to replace a weak or damaged root system of an established tree
Bridge graft	Large: 15 cm (6 in) and larger	Active; bark must be slipping	Repair injury to trunk of tree
Bracing	Limbs of tree bound by pulling together two strong young lateral shoots from limbs to be braced	Active or dormant	Natural grafting used to strengthen scaffolding limbs of a tree

Detached Scion Graftage— Apical Graftage

There are many variations of apical graftage. As the name suggests, the scion is inserted into the top of the severed rootstock shoot.

Whip-and-Tongue Graft The whip-and-tongue graft, shown in Figures 12–2 and 12–3, is particularly useful for grafting relatively small material about 6 to 13 mm (1/4 to 1/2 in) in diameter. It is highly successful if done properly because there is considerable vascular cambium contact,

**Figure 12-2**

Whip-and-tongue graft. (a) This method is widely used in grafting small plant material and is especially valuable in making root grafts as illustrated here. (b) Whip-and-tongue of bench grafted pear.

plus it heals quickly and makes a strong union. Preferably, the scion and rootstock should be of equal diameter. The scion should contain two or three buds, and the graft made in the smooth internodes area below the lower bud.

The cuts made at the top of the rootstock should be the same as those made at the bottom of the scion. First, a smooth, sloping cut is made, 2.5 to 6 cm (1 to 2 1/2 in) long; longer cuts are made when working with large material. This first cut should preferably be made with one single stroke of the knife, in order to leave a smooth, flat surface. To do this, the knife must be razor sharp. Wavy, uneven cuts made with a dull knife will not result in a satisfactory union.

On each of these cut surfaces, a reverse cut is made. It is started downward at a point about one-third of the distance from the tip and should be about one-half the length of the first cut. To obtain a smooth-fitting graft, this second cut should not just split the grain of the wood but should follow along under the first cut, tending to parallel it.

The rootstock and scion are then inserted into each other, with the tongues interlocking. It is extremely important that the vascular cambium layers match along at least one side, preferably along both sides. The lower tip of the scion should not overhang the stock, because it increases the likelihood of the formation of

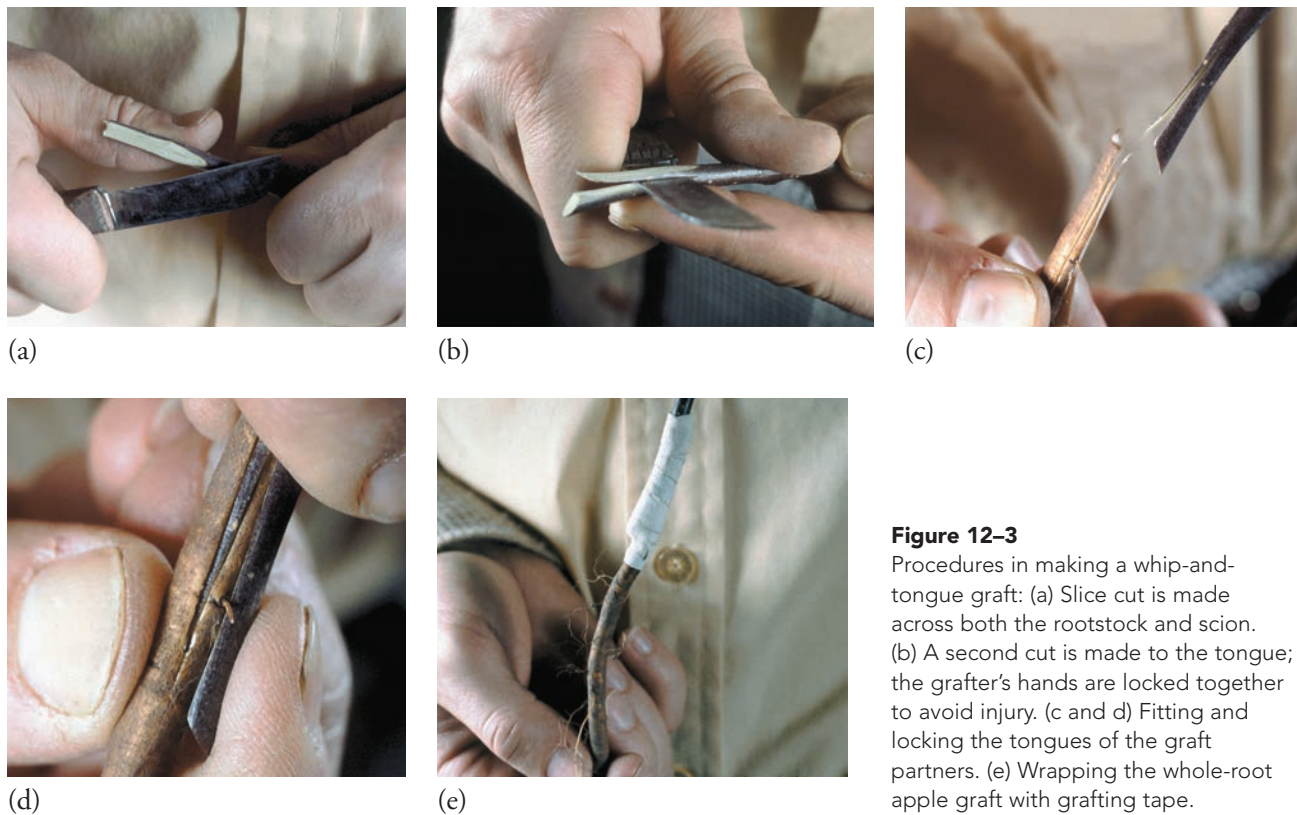


Figure 12-3

Procedures in making a whip-and-tongue graft: (a) Slice cut is made across both the rootstock and scion. (b) A second cut is made to the tongue; the grafter's hands are locked together to avoid injury. (c and d) Fitting and locking the tongues of the graft partners. (e) Wrapping the whole-root apple graft with grafting tape.

large callus knots. The use of scions larger than the rootstock should be avoided for the same reason.

After the scion and rootstock are fitted together, they are securely tied with budding rubber strips, plastic (poly) budding/grafting tape, or raffia. It is important that the tissues in the graft union area not dry out, so either sealing the graft union with grafter's wax, Parafilm, or Buddy Tape, or placing the plants under high relative humidity, is essential until the graft union has formed.

In **bench graftage** (page 502) the bare-root grafted plants can be stored in a grafting box (without sealing the graft union with grafter's wax) and packed with slightly moist peat or bark. Grafted plants in liner pots can be placed in a polytent in a temperature-controlled greenhouse (Fig. 12-4). If bare-root, bench-grafted plants are to be directly planted in a field nursery, the graft union is temporarily placed below the soil level. Any poly budding tape will need to be removed after graft union formation to prevent girdling the stem. Grafts wrapped with budding rubbers and temporarily covered with soil or media should be inspected later; the rubber decomposes very slowly below ground and may cause a constriction at the graft union.

If the whip-and-tongue graft is used in **field grafting**, the graft union of the **topworked** (page 422) plant

must be tied and sealed with grafter's wax, Parafilm, or Buddy Tape. Aftercare of grafted plants is further described in the section "Production Processes of Graftage" (page 491).

Splice Graft (Whip Graft) The splice graft is simple and easy to make (Fig. 12-5). It is the same as the whip-and-tongue graft except that the second, or "tongue," cut is not made in either the rootstock or scion. A simple slanting cut of the same length and angle is made in both the rootstock and the scion. These are placed together and wrapped or tied as described for the whip graft. If the scion is smaller than the rootstock it should be set at one side of the rootstock so that the vascular cambium layers will match along that side (Fig. 12-5).

The splice graft is particularly useful in grafting plants that have a very pithy stem or that have wood that is not flexible enough to permit a tight fit when a tongue is made as in the whip-and-tongue graft. The splice graft is used in greenhouse production of vegetable crops for grafting disease-resistant rootstocks. For vegetable crops such as cucurbits or *Solanaceae*, this graft is sometimes referred to as One Cotyledon Grafting (OCG), the slant graft, or Japanese tube graft



(c)



(a)



(b)



(d)

Figure 12-4

Polytent or closed case system for maintaining grafted plants under high relative humidity. Light intensity and temperature are controlled in the greenhouses. (a) After the grafted Japanese maples and (b) conifer grafts have callused, the poly cover is removed; the poly was temporarily lifted so the grafted plants could be photographed. (c and d) The majority of Korean and Japanese vegetables are produced from grafted plants. The grafted plants are initially placed in the dark or under very low light intensity and high relative humidity until the graft has healed. Photos c and d courtesy M. Peet.

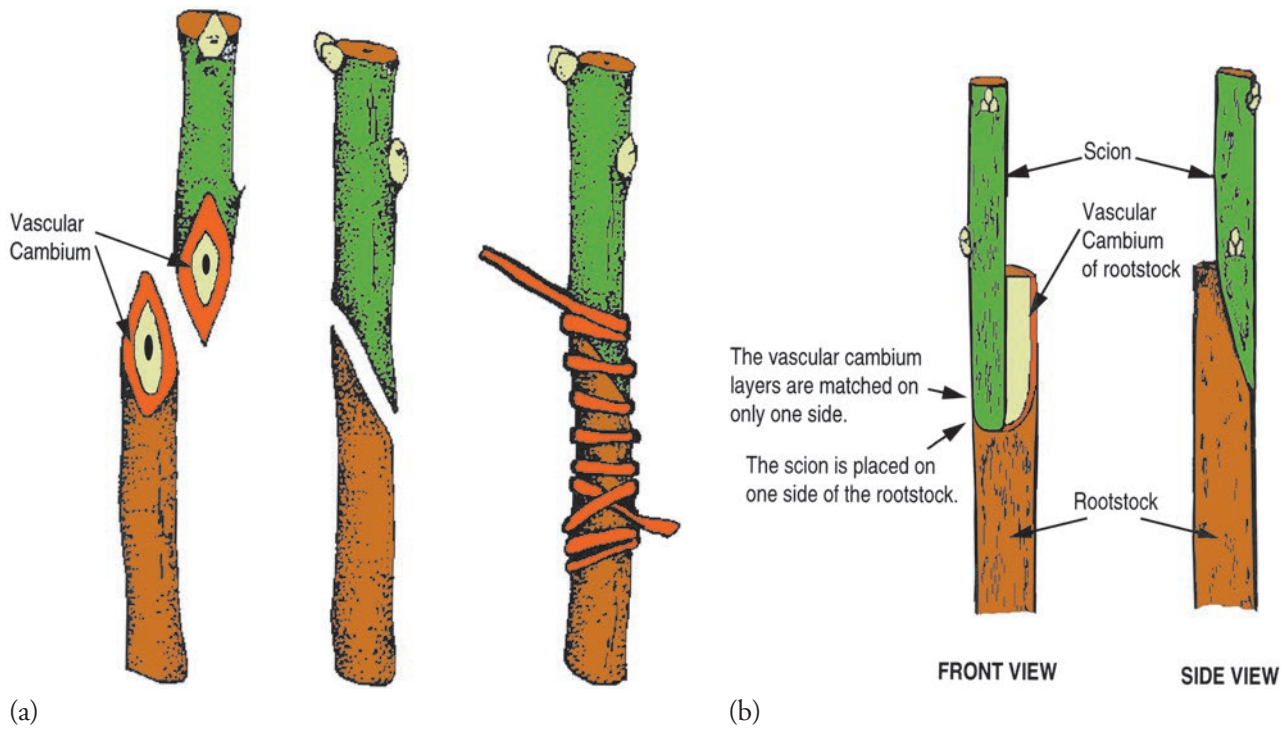


Figure 12-5

Splice graft (whip graft). (a) Procedures in making the splice graft with a slice cut that slants across the grafting partners. Ideally, the rootstock and scion are of the same caliber. (b) Method of making a splice graft when the scion is considerably smaller than the rootstock. It is important that the cambium layers be matched on one side.



BOX 12.1 GETTING MORE IN DEPTH ON THE SUBJECT
CORRECT INSERTION OF THE SCION



In all types of grafting, the scion must be inserted right side up. That is, the apical tip of the buds on the scion

should be pointing upward and away from the rootstock. The graft will not be successful if this rule is not observed.

(Figs. 12–6 and 12–7) (11, 12, 21). The graft can be performed manually or with sophisticated, robotic grafting machines; see Figures 12–43, 12–44, and 12–45, pages 498–99. The rootstock and scion must be held together while tying the splice graft. In field graft-

ing, it is not a convenient method to use at ground level, and must be performed higher up on the rootstock, where the grafter must do both the cutting and tying. The whip-and-tongue does not have this limitation, since the tongue holds the graft together, so that

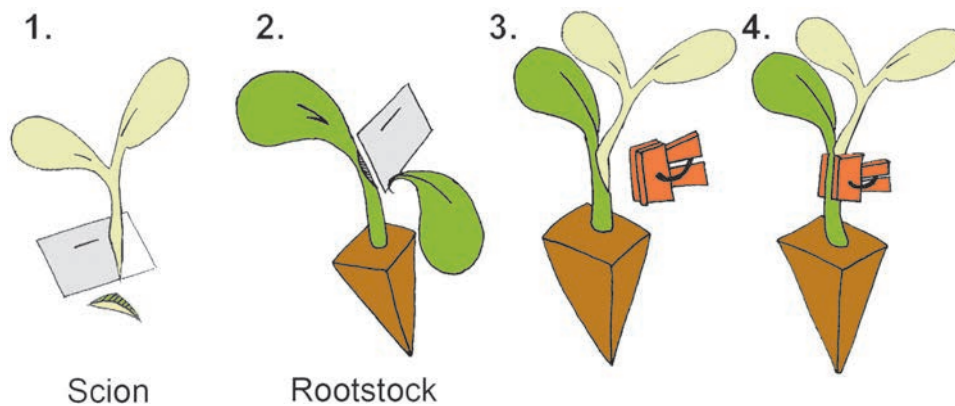


Figure 12–6
 One cotyledon grafting (OCG), which is a form of the splice graft used with cucurbit vegetable crops; also called the slant graft and Japanese tube graft (12, 21). Illustrations courtesy R. L. Hassell.

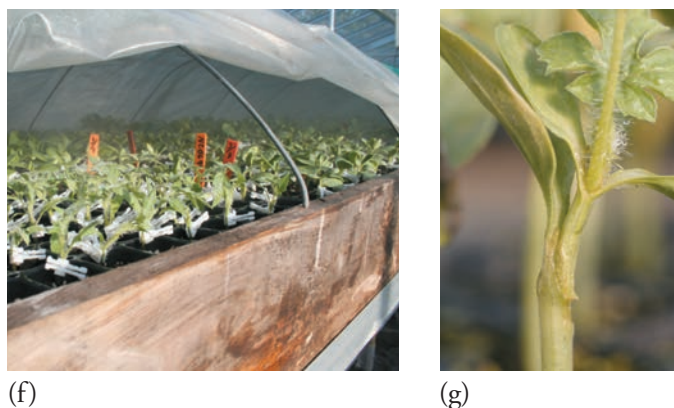
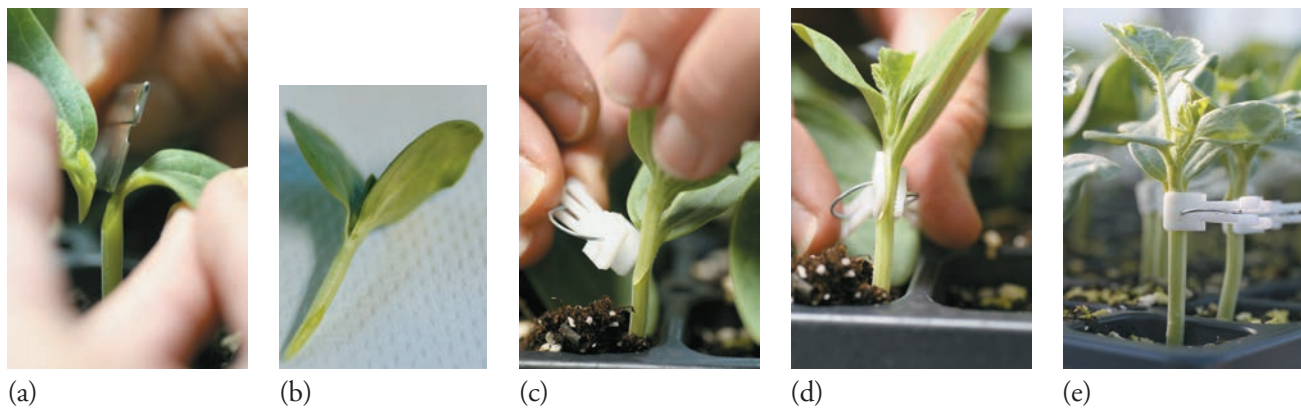


Figure 12–7
 One cotyledon grafting (OCG): A form of splice graft used with cucurbits. (a) Preparation of squash rootstock leaving a single cotyledon leaf. (b) Watermelon scion with slant cut. (c) Plastic clip used to hold scion and rootstock. (d and e) Plastic clips used to hold watermelon scion and squash rootstock. (f) Grafts are allowed to heal under very high humidity and dark to very low light conditions until graft union formation has occurred. (g) Successfully healed OCG. Photos courtesy of R. L. Hassell.



grafter The person cutting the stock and scion and inserting the scion piece.

Tier The person who completes the grafting process by tying, and sometimes waxing, the graft area.

the **grafter** has both hands free for tying, or the fitted graft can be left for a helper or “**tier**” to tie and seal. A splice graft is used in bench grafting and grafting of container plants.

topworking trees, this method should be limited to rootstock branches about 2.5 to 10 cm (1 to 4 in) in diameter, and to species with fairly straight-grained wood that will split evenly.

Although cleft grafting can be done any time during the dormant season, the chances for successful healing of the graft union are best if the work is done in early spring just when the buds of the rootstock are beginning to swell, but before active growth has started. If cleft grafting is done after the tree is in active growth, the bark of the rootstock may separate from the wood, making it difficult to obtain a good union. When this separation occurs, the loosened bark must be firmly nailed back in place. The scions should be made from dormant, 1-year-old wood. Unless the grafting is done early in the season (when the dormant scions can be collected and used immediately), the

Cleft Graft (Split Graft) The cleft or split graft is one of the oldest methods of field grafting. It is used to topwork trees, either in the trunk of a small tree or in the scaffold branches of a larger tree (Figs. 12–8 and 12–9). Cleft grafting is used for *crown grafting* (see the “Grafting Systems” section, page 504) or grafting smaller plants such as established grapevines or camellias. In

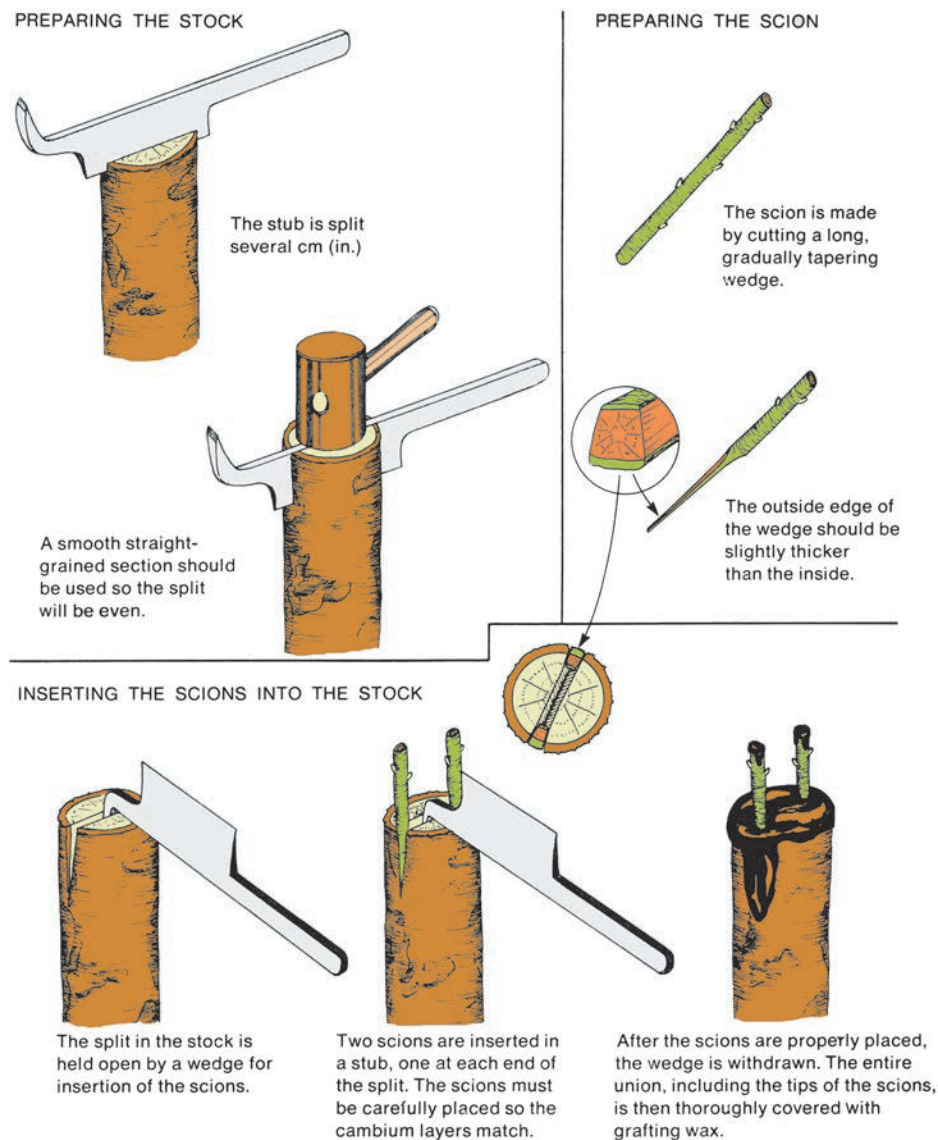
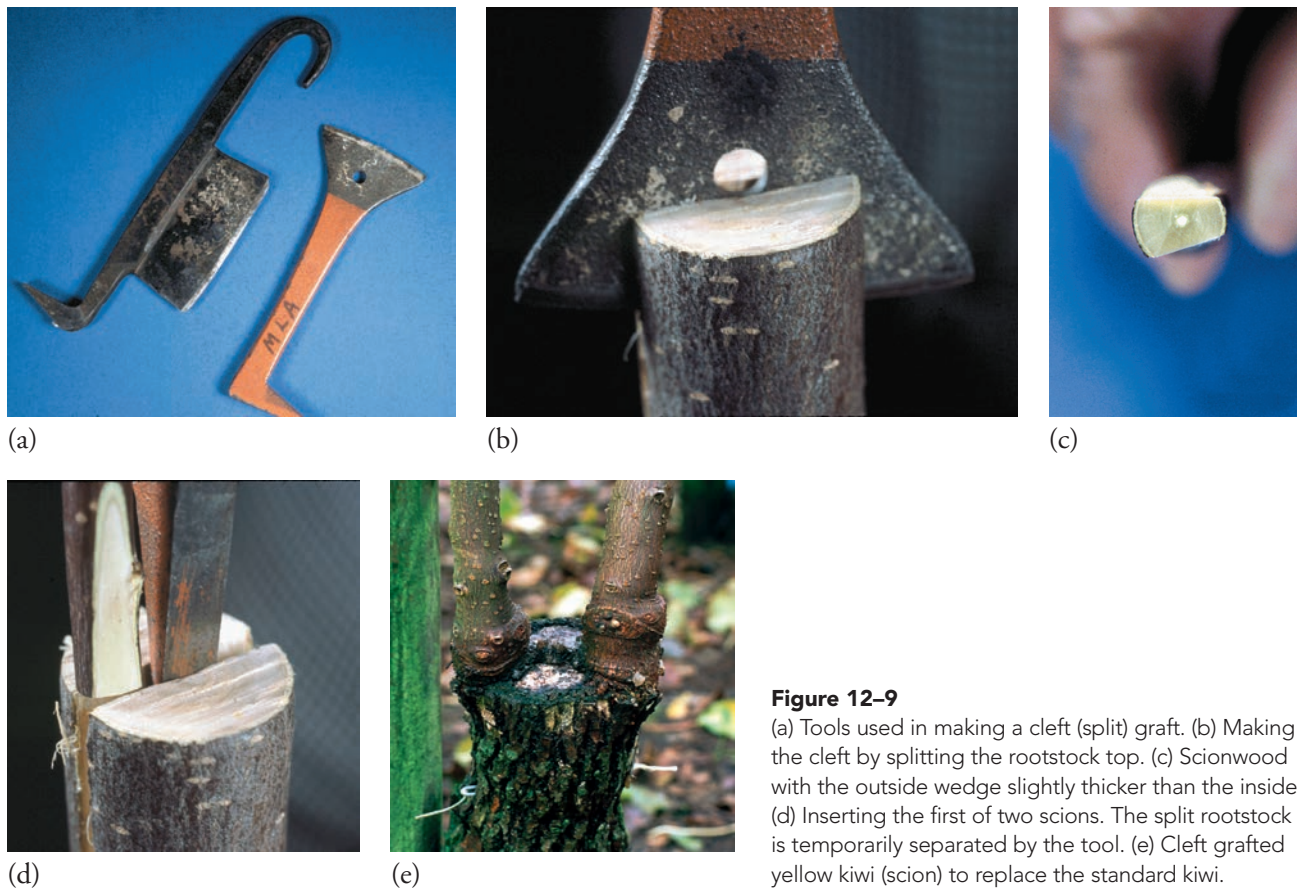


Figure 12–8

Steps in making the cleft graft (split graft). This method is very widely used and is quite successful if the scions are inserted so that the cambium layers of stock and scion match properly.

**Figure 12-9**

(a) Tools used in making a cleft (split) graft. (b) Making the cleft by splitting the rootstock top. (c) Scionwood with the outside wedge slightly thicker than the inside. (d) Inserting the first of two scions. The split rootstock is temporarily separated by the tool. (e) Cleft grafted yellow kiwi (scion) to replace the standard kiwi.

scionwood should be collected in advance and refrigerated. In sawing off the branch for this and other top-working methods, the cut should be made at right angles to the main axis of the branch.

In making the cleft graft, a heavy knife, such as a butcher knife, or one of several special cleft grafting tools, is used to make a vertical split for a distance of 5 to 8 cm (2 to 3 in) down the center of the stub to be grafted (Figs. 12-8 and 12-9). This split is made by pounding the knife in with a hammer or mallet. The branch is sawed off in such a position that the end of the stub that is left is smooth, straight-grained, and free of knots for at least 15 cm (6 in). Otherwise, the split may not be straight, or the wood may split one way and the bark another. The split should be in a tangential rather than radial direction in relation to the center of the tree to permit better placement of the scions for their subsequent growth. Sometimes the cleft is made by a longitudinal saw cut rather than by splitting. After a good, straight split is made, a screwdriver, chisel, or the wedge part of the cleft-grafting tool is driven into the top of the split to hold it open.

Two scions are inserted, one at each side of the stock where the vascular cambium layer is located. The scions should be 8 to 10 cm (3 to 4 in) long, about 10

to 13 mm ($3/8$ to $1/2$ in) thick, and should have two or three buds. The basal end of each scion should be cut into a gently sloping wedge about 5 cm (2 in) long. It is not necessary that the end of the wedge come to a point. The side of the wedge which is to go to the outer side of the rootstock should be slightly wider than the inside edge. Thus, when the scion is inserted and the tool is removed, the full pressure of the split rootstock will come to bear on the scions at the position where the vascular cambium of the rootstock touches the vascular cambium layer on the outer edge of the scion. Since the bark of the rootstock is almost always thicker than the bark of the scion, it is usually necessary for the outer surface of the scion to set slightly in from the outer surface of the rootstock in order to match the vascular cambium layers.

The long, sloping wedge cuts at the base of the scion should be smooth, a single cut on each side made with a sharp knife. Both sides of the scion wedge should press firmly against the rootstock for their entire length. A common mistake in cutting scions for this type of graft is to make the cut on the scion too short and the slope too abrupt, so that the point of contact is only at the top. Slightly shaving the sides of the split in the stock will often permit a smoother contact.



After the scions are properly made and inserted, the tool is withdrawn, without disturbing the scions, which should be held tightly by the pressure of the rootstock so that they cannot be pulled loose by hand. No further tying or nailing is needed unless very small rootstock branches have been used. In this case, the top of the rootstock can be wrapped tightly with poly grafting tape or adhesive tape to hold the scions in place more securely.

Thorough waxing of the completed graft is essential. The top surface of the stub should be entirely covered, permitting the wax to work into the split in the stock. The sides of the grafted stub should be well covered with wax as far down the stub as the length of the split. The tops of the scions should be waxed but not necessarily the bark or buds of the scion. Two or three days later, all the grafts should be inspected and rewaxed where openings appear. Lack of thorough and complete waxing in this type of graft is a common cause of failure.

Wedge Graft (Saw-Kerf Graft) Wedge grafting is illustrated in Figure 12–10. Like the cleft graft, it can be made in late winter (in mild climates) or early spring before the bark begins to slip (separates easily from the wood).

The diameter of the stock to be grafted is the same as for the cleft graft—5 to 10 cm (2 to 4 in), and the scions are also the same size—10 to 13 cm (4 to 5 in) long and 10 to 13 mm (3/8 to 1/2 in) in thickness.

A sharp, heavy, short-bladed knife is used for making a V-wedge in the side of the stub, about 5 cm (2 in) long. Two cuts are made, coming together at the bottom and as far apart at the top as the width of the scion. These cuts extend about 2 cm (3/4 in) deep into the side of the stub. After these cuts are made, a screwdriver is pounded downward behind the wedge chip from the top of the stub to knock out the chip, leaving a V-shaped opening for insertion of the scion. The base of the scion is trimmed to a wedge shape exactly the same size and shape as the opening. With the two vascular cambium layers matching, the scion is tapped downward, firmly into place, and slanting outward slightly at the top so that the vascular cambium layers cross. If the cut is long enough and gently tapering, the scion should be so tightly held in place that it would be difficult to dislodge.

In a stub that is 5 cm (2 in) wide, 2 scions should be inserted 180 degrees apart; in a 10-cm (4 in) stub, 3 scions should be used, 120 degrees apart. After all scions are firmly tapped into place, all cut surfaces, including the tips of the scion, should be waxed thoroughly.

Saddle Graft The saddle graft can be bench grafted by hand or machine (see Fig. 12–41, page 497). The rootstock and scion should be the same size. The scion is prepared by cutting upward through the bark and into

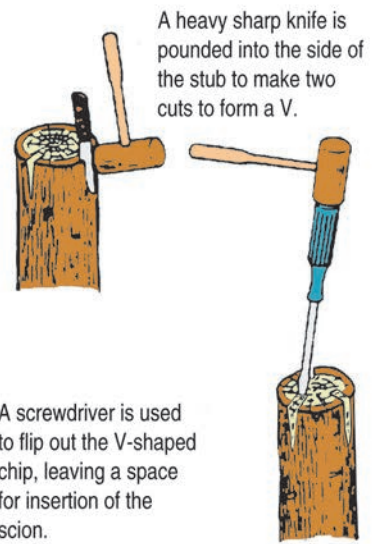
the wood on opposite sides of the scion (Fig. 12–11, page 476). The knife should penetrate more deeply into the wood as the cuts are lengthened. Before the knife is withdrawn, it is turned towards the middle of the scion piece, and the saddle shape is gradually formed by removing pieces of the wood. The rootstock is cut transversely and receives two upward cuts on either side to expose the vascular cambium of the rootstock, in order to match vascular cambium in the saddle of the scion. The apex of the rootstock is carved to fit the saddle. The graft needs to be tied, and all exposed cut surfaces sealed or stored in a grafting case until the graft union has formed. The saddle graft is used for bench grafting grape and *Rhododendron* cultivars (19).

Four-Flap Graft (Banana Graft) The four-flap graft is used in topworking small-caliper trees or tree limbs up to 2.5 cm (1 in) in diameter. This field graft is normally done manually [Figs. 12–12 (page 476) and 12–13 (page 477)], but there is a tool that aids in stripping the rootstock bark flaps from the wood (Fig. 12–13). Both the scion and rootstock should be of equal diameter, and the best fit is obtained when the scion is slightly larger than the rootstock. The four-flap graft is done with pecans in Texas from April to mid-May, when the rootstock bark is actively slipping (39). Scionwood, which is collected while dormant during the winter, is taken from cold storage and used immediately.

The rootstock with a primary stem or lateral limb is severed horizontally with sharp pruning shears. On the rootstock where the horizontal cut was made, 4 vertical, equally spaced cuts 4 cm (1.5 in) long are made with a grafting knife that penetrates from the bark down to the interior wood. A 15 cm (6 in) piece of scionwood with 3 axillary buds is cut on 4 sides with a knife. Cuts are made on the scion through the bark down to the wood—without removing much wood. There should be 4 thin slivers of bark, with the vascular cambium at the corners, which gives the prepared scion a square diameter appearance. The 4 flaps of bark are pulled down 4 cm (1.5 in) on the rootstock, and the inner wood is removed with pruning shears. The scion piece is inserted upright on the rootstock and the 4 flaps of the rootstock are pulled up to cover the 4 cut surfaces of the scion. A rubber band is rolled up onto the flaps to hold them in place. The cut flap areas are then tied with flagging tape, green floral tape, or white budding tape. The tip of the scion is painted with tree paint or sealed with white glue to prevent it from drying out.

Then the taped graft area is covered with aluminum foil to protect it from heat. A hole is made in the corner of a clear poly bag (freezer bag) and the poly

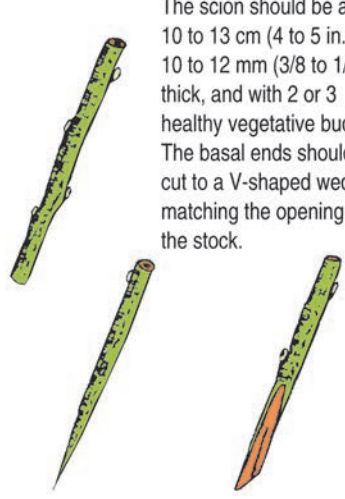
PREPARING THE ROOTSTOCK



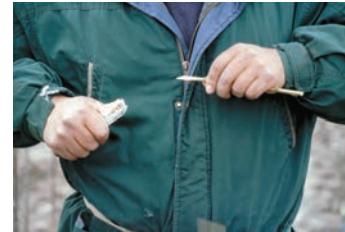
A heavy sharp knife is pounded into the side of the stub to make two cuts to form a V.

A screwdriver is used to flip out the V-shaped chip, leaving a space for insertion of the scion.

PREPARING THE SCION



The scion should be about 10 to 13 cm (4 to 5 in.) long, 10 to 12 mm (3/8 to 1/2 in.) thick, and with 2 or 3 healthy vegetative buds. The basal ends should be cut to a V-shaped wedge, matching the opening in the stock.

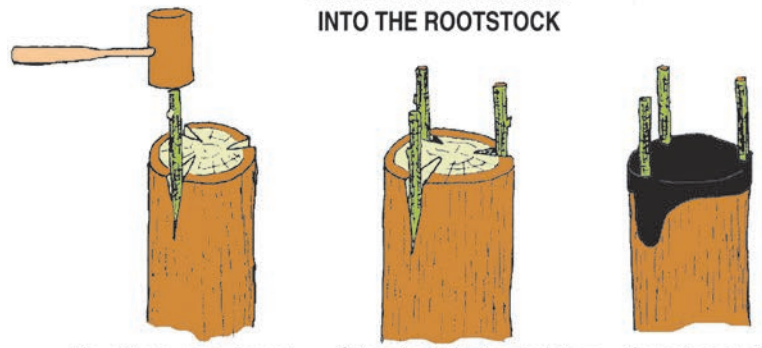


(b)



(c)

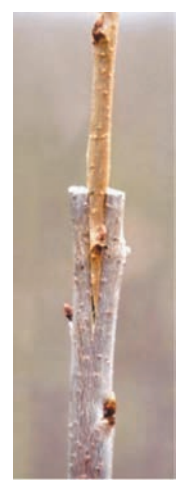
INSERTING THE SCIONS INTO THE ROOTSTOCK



The scion is gently tapped into the V-shaped opening in the stock, matching the cambium layers at a slight angle so that the cambium of stock and scion cross.

Scion should be inserted at an angle so that the cambium layers of stock and scion are closely matched, barely crossing each other.

After scions are in place all cut surfaces are thoroughly covered with grafting wax.



(d)

(a)



(e)



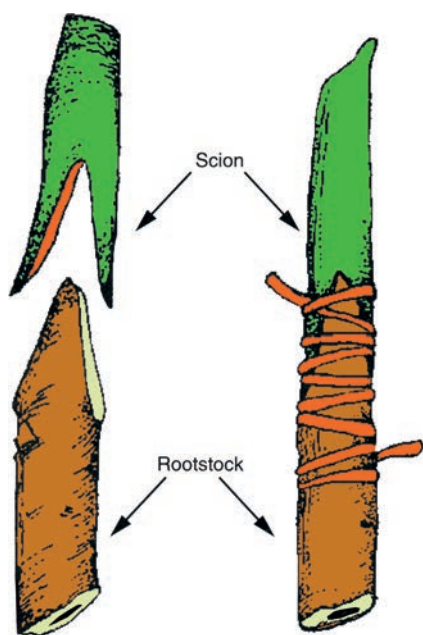
(f)



(g)

Figure 12-10

(a) Wedge graft (saw-kerf graft). Sometimes called the saw-kerf because the cuts in the side of the rootstock can be made with a saw, rather than with the sharp tool depicted. (b, c, d, e, and f) Wedge graft of cherry whips in field using one scion piece. (b) Trimming scionwood with grafting knife, (c and d) inserting scionwood into rootstock, (e) wrapping graft with poly, (f) sealing with grafting wax—notice wax container (arrow) and (g) tied graft with poly and grafting wax covering bottom of scion and graft union area (arrow) used to fill in tissue separation.

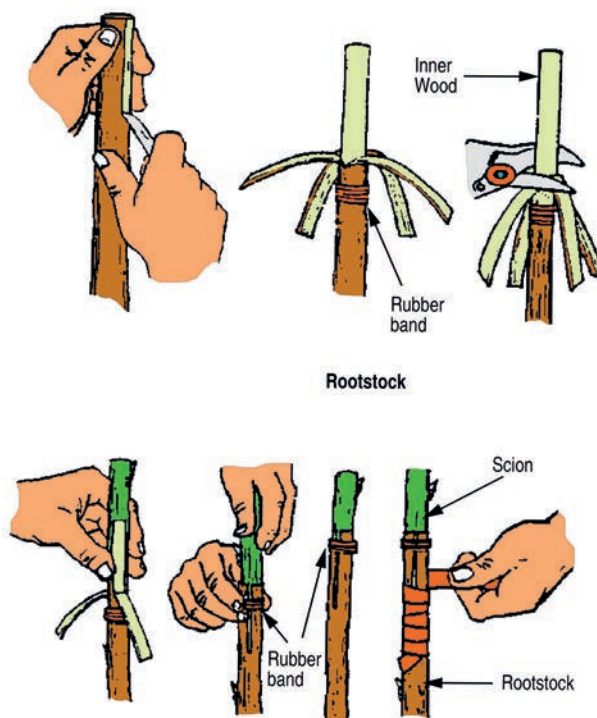
**Figure 12-11**

Steps in making the saddle graft. The scion is cut to have a saddle appearance and the understock to form a blunt point. The cambium layers are matched up and the graft tied.

slid down over the graft area so that it is just covering the aluminum foil (no poly should cover the apex of the scion, nor should it touch any exposed wood). Air is expelled so the poly fits snugly over the aluminum foil, and it is tied at both ends with stretchable plastic budding tape or rubber bands. The function of the poly bag is to maintain a high relative humidity in the graft area. In 4 to 6 weeks after the graft has taken, the ties, poly bag, and aluminum foil are removed.

The vegetative growth of the rootstock plant must be kept in check, since many new shoots will appear on the rootstock below the graft. Some of these shoots are needed for maintaining tree vigor, but the rootstock shoots should not become dominant or exceed the height of the scion—the growing tips of the rootstock shoots will have to be removed several times during the growing season. After 2 to 3 years, all rootstock branches are removed below the graft and the scion becomes the dominant shoot system.

Hole Insertion Graft (HIG) or Terminal/Top Insertion Graft This technique is used for grafting watermelon to squash rootstock (12, 21). This is most popular graft used in China because it is suitable for *Lagenaria* (Cucurbita) and interspecific squash as rootstocks, requires few materials, is highly efficient (1,500+ plants/day/worker), and allows simpler management techniques (34). When both cotyledons and first true leaf start to develop, the rootstock plant is ready to graft (7 to 10 days after sowing). Remove the growing point with a sharp probe, and then

**Figure 12-12**

The four-flap or banana graft. *Top*: The top of the rootstock is cut horizontally, and the bark is cut vertically into four strips. The four bark flaps are peeled down and the inner wood removed. *Middle*: The scion bark is removed and the wood retained. The flaps of the rootstock cover the cut surfaces of the scionwood and are temporarily held by a rubber band. The graft is then tied with white grafting tape. *Bottom left*: Aluminum foil is wrapped around the graft to exclude heat from the graft. *Bottom right*: The grafted area covered with aluminum foil is wrapped with a cut poly bag, which is sealed to retain high relative humidity until the graft takes (39).

open a hole on the upper portion of the rootstock hypocotyl with a bamboo needle or 1.4-mm drill bit. The scion is then cut on a 35- to 45-degree angle, on both sides, on the hypocotyls and inserted into the hole made in the rootstock. The cut surfaces are matched together, held with or without a grafting clip and transferred to a humidity chamber or healing room. Grafted plants should not be older than 33 days before transplanting (Figs. 12-14 and 12-15, page 478) (21).



Figure 12-13

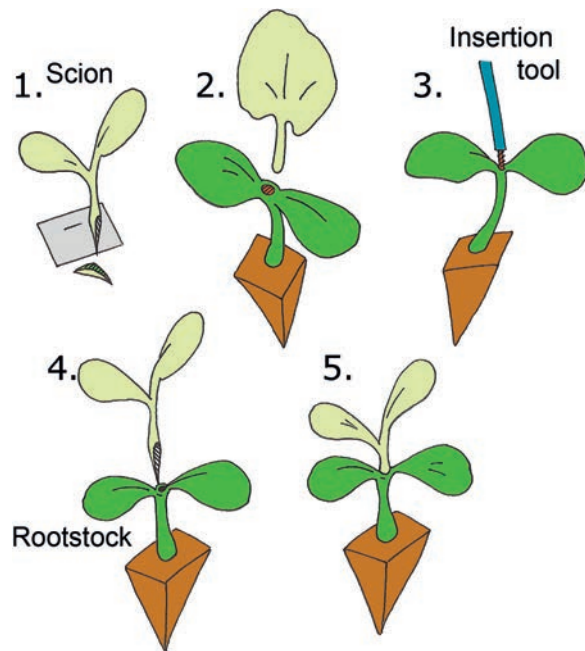
Steps in the four-flap or banana graft. (a) Preparing the rootstock by severing the rootstock top. (b) The four bark flaps of the rootstock with the "wood" of the rootstock removed. (c and d) Prepping the scion by removing the bark of the scion with wood left intact. (e and f) Flaps of the rootstock cover the cut surfaces of the scionwood and are temporarily held by grafting tape, then covered with aluminum foil and poly to prevent desiccation. (g and h) A tool for the four-flap graft, which is slid over the rootstock and used to cut and peel the four flaps.

Detached Scion Graftage—Side Grafting

There are many types of side graftage. As the name suggests, the scion is inserted into the side of the rootstock, which is generally larger in diameter than the scion. This method has proven useful for large-scale propagation of nursery trees (36). Generally, the rootstock

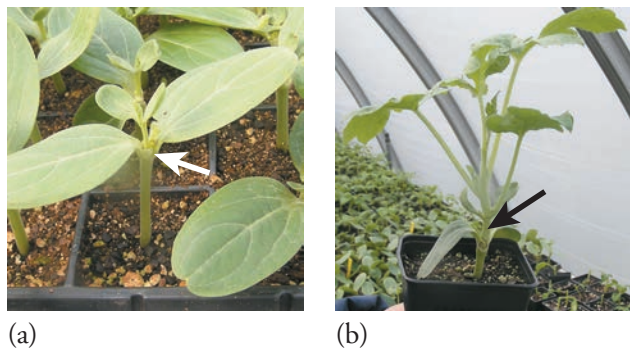
shoot is removed after the graft takes, and the scion becomes the dominant shoot system.

Side-Stub Graft The side-stub graft is useful in grafting branches of trees that are too large for the whip-and-tongue graft, yet not large enough for other methods such

**Figure 12-14**

Hole insertion graft (HIG) or terminal/top insertion graft (12, 21).

Illustrations courtesy R. L. Hassell.

**Figure 12-15**

(a and b) Hole insertion graft (HIG) for grafting watermelon to squash rootstock. This is the most popular graft used in China because it is suitable for *Lagenaria* (*Cucurbita*) and interspecific squash as rootstocks, requires few materials, has high efficiency, 1500+ plants/day/worker, and simpler management techniques (34). Photos courtesy of R. L. Hassell.

as the cleft or bark graft. For this type of side graft, the best rootstocks are branches about 2.5 cm (1 in) in diameter. An oblique cut is made into the rootstock branch with a chisel or heavy knife at an angle of 20 to 30 degrees. The cut should be about 2.5 cm (1 in) deep and at such an angle and depth that when the branch is pulled back, the cut will open slightly but will close when the pull is released.

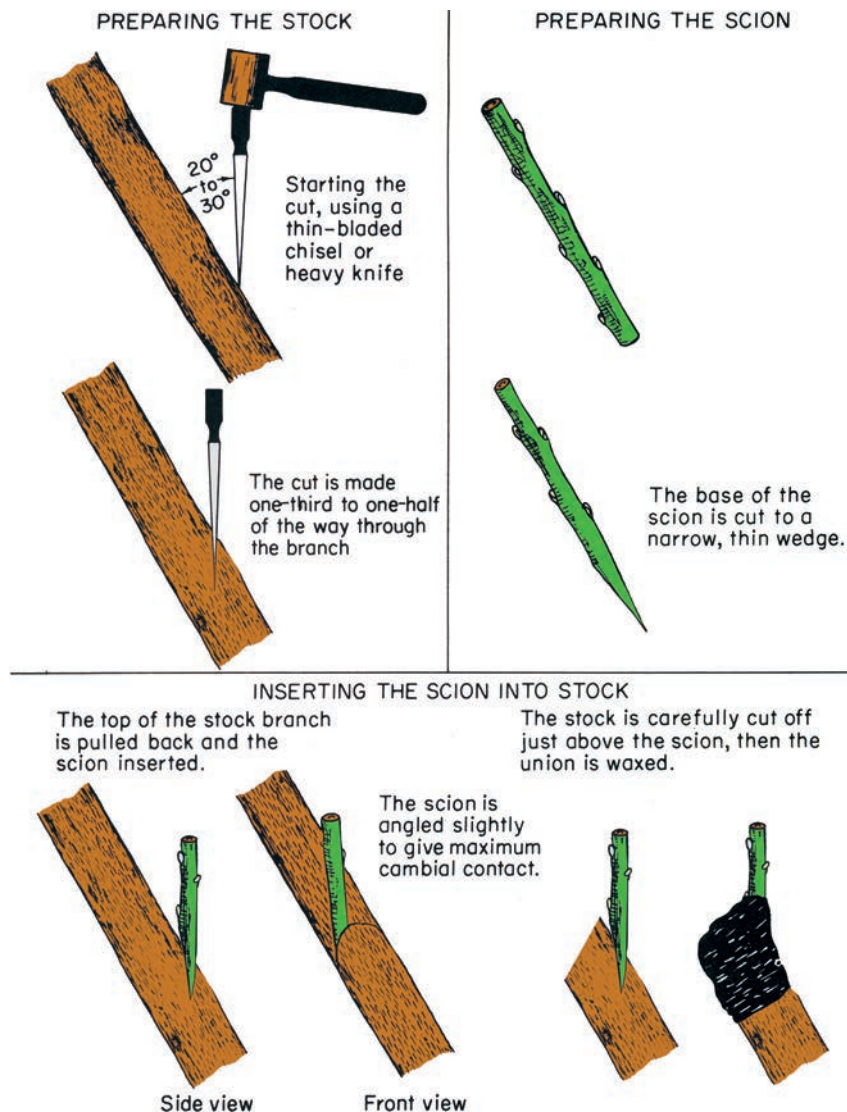
The scion should contain two or three buds and be about 7.5 cm (3 in) long and relatively thin. At the

basal end of the scion, a wedge about 2.5 cm (1 in) long is made. The cuts on both sides of the scion should be very smooth, each made by one single cut with a sharp knife. The scion must be inserted into the rootstock at an angle, as shown in Figure 12-16, to obtain maximum contact of the vascular cambium layers. The grafter inserts the scion into the cut while the upper part of the rootstock is pulled backward, being careful to obtain the best cambium contact, then the rootstock is released. The pressure of the rootstock should grip the scion tightly. The scion can be further secured by driving two small flat-headed wire nails [20 gauge, 1.5 cm (5/8 in) long] into the stock through the scion. Wrapping the rootstock and scion at the point of union with nursery tape also may be helpful. After the graft is completed, the rootstock may be cut off just above the union. This must be done very carefully or the scion may become dislodged. The entire graft union must be thoroughly covered with grafting wax, sealing all openings. The tip of the scion also should be covered with wax or sealed with white glue (57).

Side-Tongue Graft The side-tongue graft, shown in Figure 12-17, page 480, is useful for small plants, especially some of the broad- and narrow-leaved evergreen species. The rootstock plant should have a smooth section in the stem just above the crown of the plant. The diameter of the scion should be slightly smaller than that of the rootstock. The cuts at the base of the scion are made in the same way as for the whip-and-tongue graft. Along a smooth portion of the stem of the rootstock a thin piece of bark and wood, the same length as the cut surface of the scion, is completely removed. Then a reverse cut is made downward in the cut on the rootstock starting one-third of the distance from the top of the cut. This second cut in the rootstock should be the same length as the reverse cut in the scion. The scion is then inserted into the cut in the rootstock, the two tongues interlocking, and the vascular cambia matching. The graft is wrapped tightly, using one of the methods described for the whip-and-tongue graft.

The top of the rootstock is left intact for several weeks until the graft union has started to heal. Then it may be cut back above the scion gradually or all at once to force the buds on the scion into active growth.

Side-Veneer Graft The side-veneer graft is widely used for grafting small potted liner plants such as seedling conifers, deciduous trees and shrubs, and fruit crops (Figs. 12-18, 12-19, and 12-20, pages 480-83). A shallow downward and inward cut from 25 to 38 mm (1 to 1 1/2 in) long is made in a smooth area just above the crown of the rootstock. At the base of this cut, a second

**Figure 12-16**

Steps in preparing the side-stub graft. A thin-bladed chisel, as illustrated here, is ideal for making the cut, but a heavy butcher knife could be used satisfactorily.

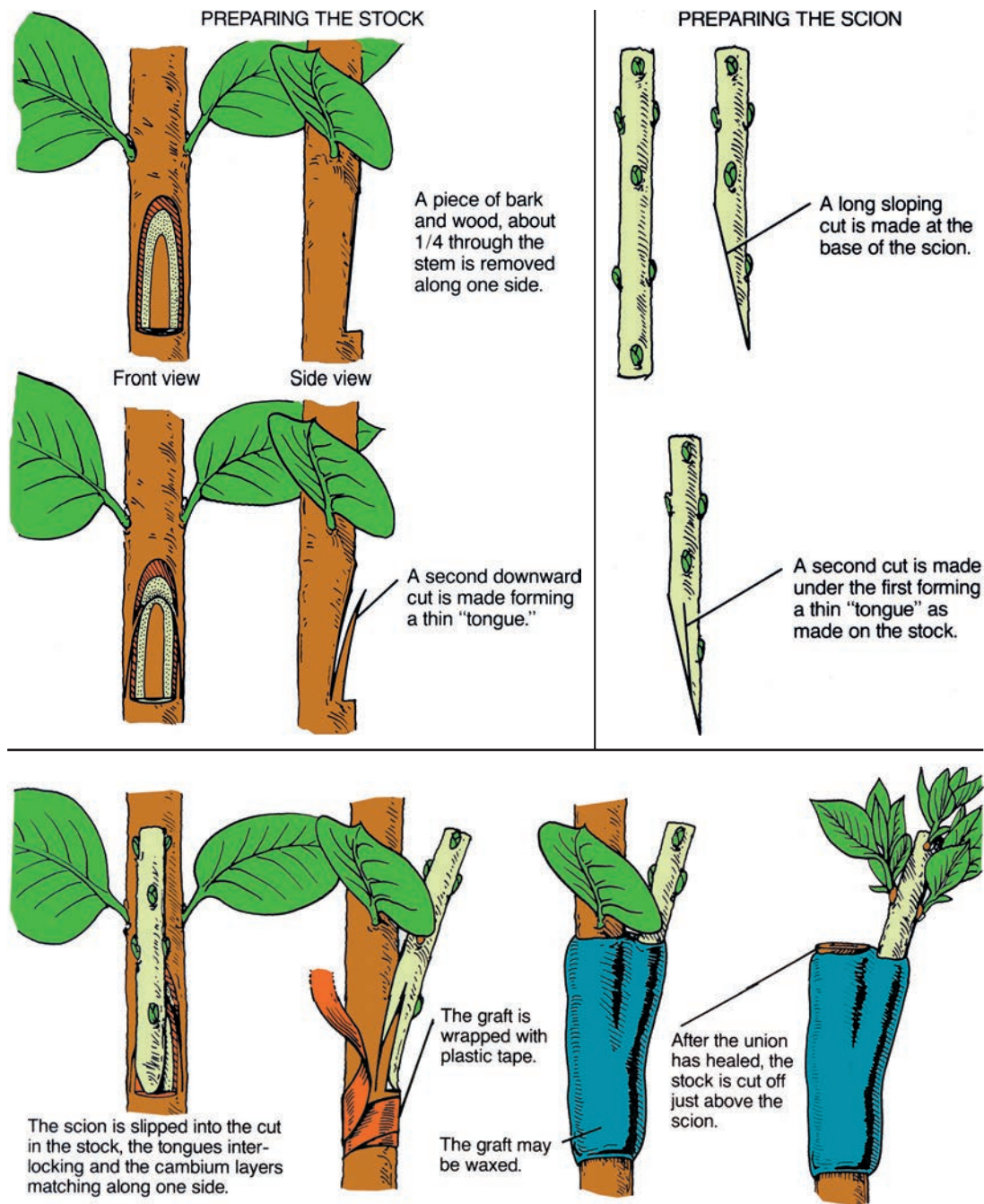
short inward and downward cut is made, intersecting the first cut, that removes the piece of wood and bark. The scion is prepared with a long cut along one side and a very short one at the base of the scion on the opposite side. These scion cuts should be the same length and width as those made in the rootstock so that the vascular cambium layers can be matched as closely as possible.

After inserting the scion, the graft is tightly wrapped with poly budding strips, budding rubbers, Buddy Tape, or with nursery adhesive tape. The graft may or may not be covered with wax, depending upon the species. A common practice in side grafting small potted plants of some woody ornamental species is to plunge the grafted plants into a slightly moist medium, such as peat moss, so that it just covers the graft union. Inserting the grafted liner plants in polytents in temperature-controlled greenhouses is another common practice (Fig. 12-4). To maintain high humidity, the

newly grafted plants may also be placed for healing in a mist propagating house (but the grafts are not directly placed under mist), or set in grafting cases. The latter are closed boxes with a transparent cover, which permits retention of high humidity around the grafted plant until the union has healed. The grafting cases are kept closed for a week or so after the grafts are put in, and then gradually opened over a period of several weeks; finally, the cover is taken off completely.

After the union has healed, the rootstock can be cut back above the scion either in gradual steps or all at once.

Side Insertion Graft (SIG) The Side Insertion Graft (SIG) has been largely replaced by the OCG or Japanese tube graft, hole insertion graft (HIG), and tongue approach graft (TAG) (12, 21). The SIG is suitable for rootstocks with wide hypocotyls (Fig. 12-21, page 483). Production of rootstocks and scions is the

**Figure 12-17**

Sidetongue graft. This method is very useful for grafting broadleaved evergreen plants. Final tying may be done with budding rubbers, poly tape, or waxed string. The graft may be waxed, or wrapped with a sealing tape such as Parafilm or Buddy Tape.

same as that described for hole insertion grafting. A slit is cut on the hypocotyl of the rootstock with a razor blade and held open with a toothpick. A 35- to 45-degree-angle cut, on both sides is made on the hypocotyl of the scion. Then the scion is inserted into the slit in the hypocotyl of the rootstock and the toothpick is removed. Two cut surfaces are matched together and held with a grafting clip or silicone sleeve. The top

of the rootstock is cut off 5 days after grafted plants are moved from the high-humidity growth chamber (21).

Detached Scion Graftage—Bark Grafting

Bark grafting is done in topworking established plants. The rootstock must be in an active stage of growth so that the bark will slip. The scion is inserted between the bark and wood of the rootstock. Bark grafting can be

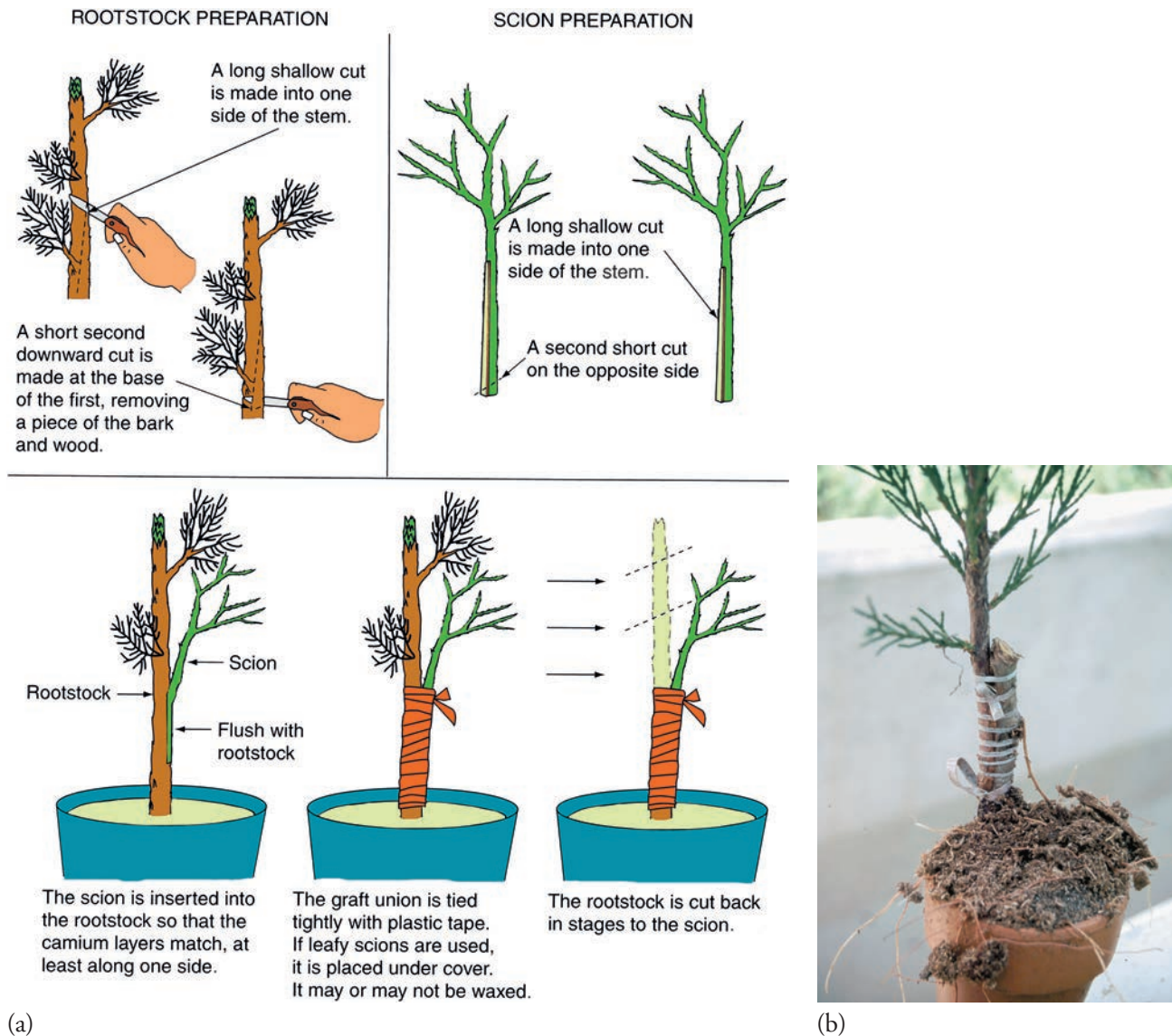


Figure 12-18

(a) Steps in making the side-veener graft. This method is one of the most popular grafts for propagating conifers and shrubs. The graft is quite versatile and can be used on a larger number of species than other grafts, such as the whip-and-tongue.
 (b) Side-veener grafted conifer.

performed on branches ranging from 2.5 cm (1 in) up to 30 cm (1 ft) or more in diameter. The latter size is not recommended, because it is difficult to heal over such large stubs before decay-producing organisms attack.

Scions must be collected for deciduous species during the dormant season and held under refrigeration. For evergreen species, freshly collected scionwood can be used. In the bark graft, scions are not as securely attached to the rootstock as in some of the other methods and are more susceptible to wind breakage during the first year, even though healing has been satisfactory. Therefore, the new shoots arising from the scions probably should be staked during the first year, or cut back to about half their length, especially in windy areas.

After a few years' growth, the bark graft union is as strong as the unions formed by other methods. *Two modifications of the bark graft are described next.*

Bark Graft (Rind Graft) Several scions are inserted into each rootstock stub (Fig. 12-22, page 484). For each scion, a vertical knife cut 2.5 to 5 cm (1 to 2 in) long is made at the top end of the rootstock stub through the bark to the wood. The bark is then lifted slightly along both sides of this cut, in preparation for the insertion of the scion. The dormant scions should be 10 to 13 cm (4 to 5 in) long, contain 2 or 3 buds, and be 6 to 13 mm (1/4 to 1/2 in) thick. One cut—about 5 cm (2 in) long—is made along one side at the base of the scion. With large scions,



(a)



(b)



(c)



(d)



(e)

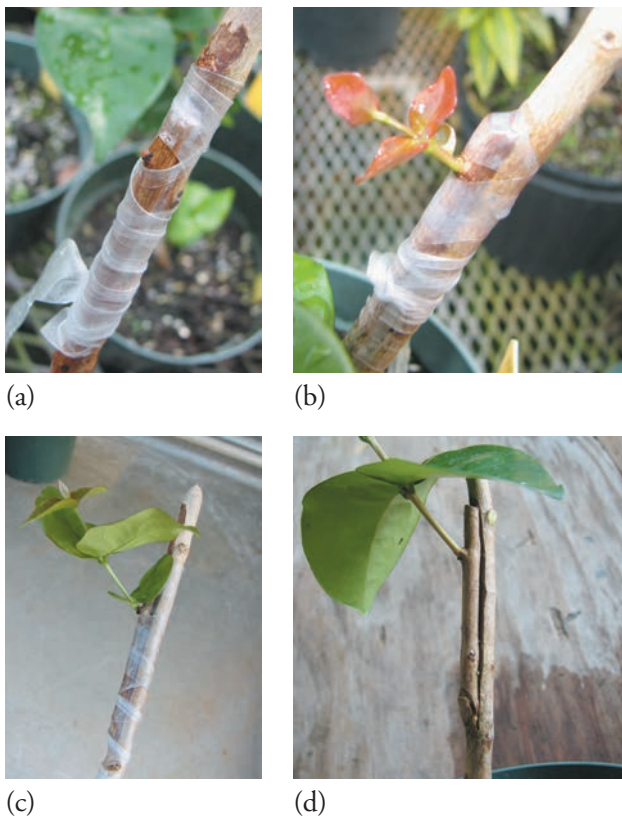
Figure 12-19

(a) Cultivars of the highly diverse Japanese maple (*Acer palmatum*) are grafted onto seedling rootstock. (b and c) A budding rubber (arrow) is used to wrap the dormant, leafless scion to the rootstock. (d) Side-veneer-grafted Japanese maples in potted liner pots which will be moved to a polytunnel area for callusing, and (e) post-allusing liner production.

this cut extends about one-third of the way into the scion, leaving a “shoulder” at the top. This shoulder reduces the thickness of the scion to minimize the separation of bark and wood after insertion in the rootstock. The scion should not be cut too thin, or it will be mechanically weak and break off at the point of attachment to the rootstock. If small scions are used, no shoulder is necessary. On the side of the scion opposite the first long cut, a second, shorter cut is made, as shown in Figure 12-22, bringing the basal end of the scion to a wedge shape. The scion is then inserted between the bark and the wood of the rootstock, centered directly under the vertical cut through the bark. The longer cut on the scion is placed against the wood, and the scion’s shoulder is brought down until it rests on top of the stub. The scion is then ready to be fastened in place. The scion is nailed into the wood, using two nails per scion. Flat-headed nails 15 to 25 mm (5/8 to 1 in) long, of 19- or 20-gauge wire, depending on the size of the scions, are satisfactory. The bark on both sides of the scion should be nailed down securely or it will tend to peel back from the wood.

Another method commonly used with soft-barked trees, such as the avocado, is to insert all the scions in the stub and then hold them in place by wrapping waxed string, adhesive tape, or poly budding tape around the stub. This method is more effective than nailing for preventing the scions from blowing out, but probably does not give as tight a fit. A combination of nailing and wrapping are advisable for maximum strength. If a wrapping material is used, it must be checked to avoid constricting the rootstock. After the stub has been grafted and the scions fastened by nailing or tying, all cut surfaces, including the end of the scions, should be covered thoroughly with grafting wax.

Inlay Bark Graft Two knife cuts about 5 cm (2 in) long are made through the bark of the rootstock down to the wood, rather than just one (Fig. 12-23, page 485). The distance between these two cuts should be exactly the same as the width of the scion. The piece of bark between the cuts should be lifted and the terminal two-thirds cut off. The scion is prepared with a smooth

**Figure 12-20**

Side veneer graft of *Eugenia* (Myrtaceae). (a, b, and c) Graft wrapped with Parafilm tape. (d) Healed graft. Photos courtesy John Griffis.

slanting cut along one side at the basal end, completely through the scion. This cut should be about 5 cm (2 in) long but without the shoulder, in contrast to the bark graft. On the opposite side of the scion, a cut about 13 mm (1/2 in) long is made, forming a wedge at the base of the scion. The scion should fit snugly into the opening in the bark with the longer cut inward and with the wedge at the base slipped under the flap of remaining bark.

The scion should be nailed into place with two nails, the lower nail going through the flap of bark covering the short cut on the back of the scion. If the bark

along the sides of the scion should accidentally become disturbed, it must be nailed back into place. Flat-point staples in the vertical position, or budding or flagging tape have all been used to secure the graft (40). The inlay bark graft is well adapted for use with thick-barked trees, such as walnuts and pecans, on which it is not feasible to insert the scion under the bark; it is used when topworking an existing orchard (Fig. 12-24, page 486).

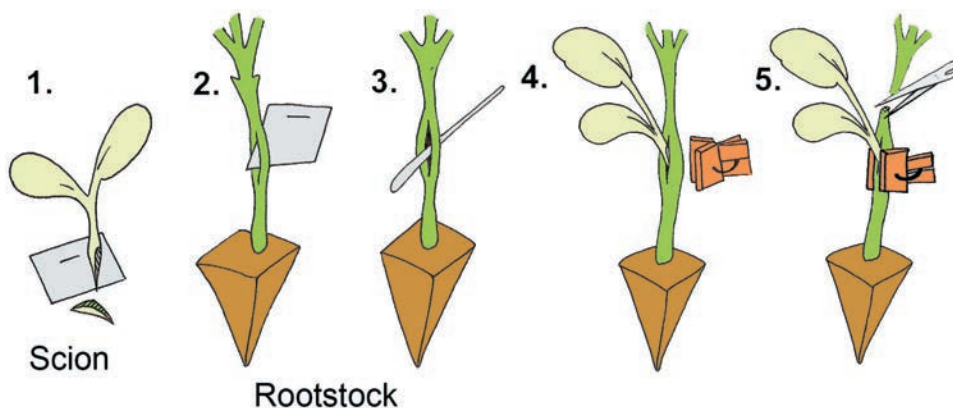
Detached Scion Graftage—Root Graftage

A number of plants are propagated commercially by root grafting—apples, pears, grapes, and selected woody ornamental shrubs and trees (17, 18).

Root Grafting (Whole-Root and Piece-Root Graftage)

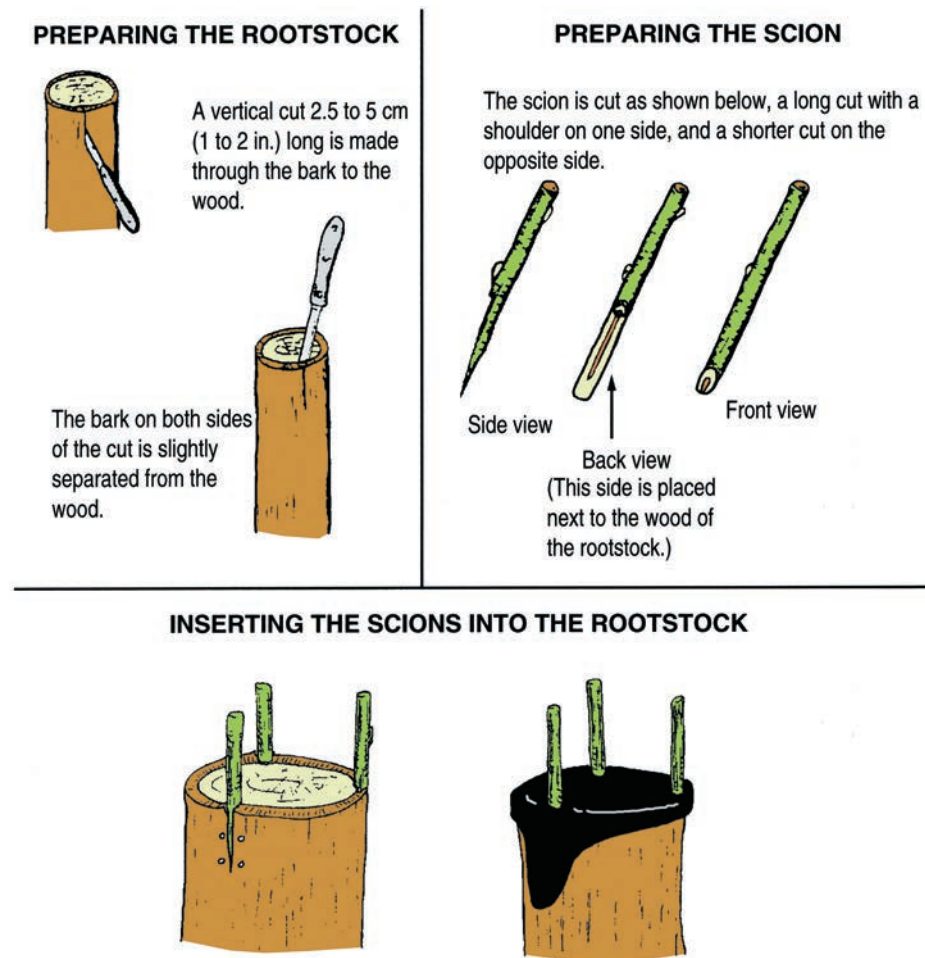
In root grafting, the rootstock seedling, rooted cutting, or layered plant is dug up, and the roots are used as the rootstock for the graft. The entire root system may be used (**whole-root graft**—Figs. 12-3 and 12-25, page 487), or the roots may be cut up into small pieces and each piece used as a rootstock (**piece-root graft**—Fig. 12-25). Both methods give satisfactory results. Since the roots used are relatively small [0.6 to 1.3 cm (1/4 to 1/2 in) in diameter], the **whip-and-tongue graft** is frequently used. In England, *Rhododendron* cultivars are saddle-grafted on roots of *R. ponticum*; the root graft is then tied and placed in a propagation case (19). Tree peony and herbaceous peony are root-grafted with a cleft graft using the root of herbaceous peony. Root grafts are usually bench-grafted indoors during the late winter or early spring. The scionwood collected previously is held in storage, while the rootstock plants are also dug in the late fall and stored under cool [1.5 to 4.5°C (35 to 40°F)] and moist conditions until the grafting is done. The term *bench grafting* is given to this process, because it is performed indoors with dormant scions and rootstocks at benches by skilled grafters as part of a large-scale operation.

In making root grafts, the root pieces should be 7.5 to 15.0 cm (3 to 6 in) long and the scions about the same length, containing 2 to 4 buds. After the grafts are

**Figure 12-21**

Steps in preparing the Side Insertion Graft (SIG). The SIG has been largely replaced by the OCG or Japanese tube graft hole insertion graft (HIG), and tongue approach graft (TAG). The SIG is suitable for rootstocks with wide hypocotyls (12, 21).

Illustrations courtesy R. L. Hassell.

**Figure 12-22**

Steps in preparing the bark graft (rind graft). In grafting some thick-barked plants, the vertical cut in the bark is unnecessary; the scion is inserted between the bark and wood of the stock.

made and properly tied, they are bundled together in groups of 50 to 100 and stored for callusing in damp sand, peat moss, or other packing material.

Nurse-Root Grafting Stem cuttings of a difficult-to-root species can sometimes be induced to develop adventitious roots by making a temporary “nurse-root” graft. The plant to be

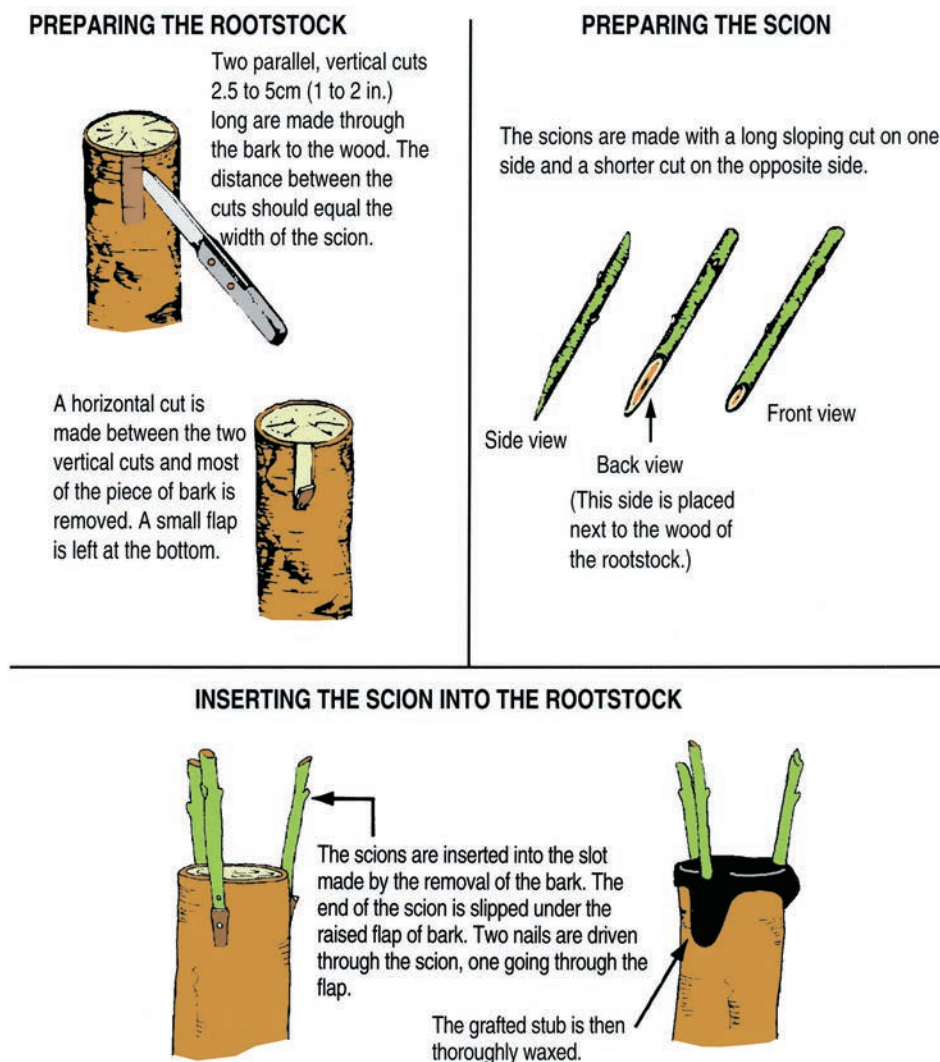
scion rooting The development of adventitious roots from the grafted scion, desirable in **nurse-root grafting**, which is a temporary graft, but problematic in other grafts where the size control or disease-resistant characteristics of the rootstock may be lost.

grown on its own roots is temporarily grafted as the scion. The scion may be made longer than usual and the graft planted deeply, with the major portion of the scion below ground. **Scion rooting** can be promoted by applying an auxin, such as indole-3-butyric acid, into several vertical cuts made through the bark at the base of the scion, above the graft union before planting. The grafts are set deeply, so that most of the scion is

covered (mound layered) with soil (28). After one season of growth the scions have roots, and the temporary nurse rootstock is cut off and discarded. The rooted scion is replanted to grow on its own roots; it can later be used as a rootstock and grafted to a scion fruit cultivar.

covered (mound layered) with soil (28). After one season of growth the scions have roots, and the temporary nurse rootstock is cut off and discarded. The rooted scion is replanted to grow on its own roots; it can later be used as a rootstock and grafted to a scion fruit cultivar.

Methods of nurse-root grafting include *reversing the polarity of the nurse-root rootstock*. The rootstock piece will eventually die if it is grafted onto the scion in an inverted position (Fig. 12-26, page 487) (37). A graft union is formed—the inverted rootstock piece sustains the scion until it roots—but the rootstock fails to receive sufficient carbohydrates from the scion and eventually dies, leaving the scion on its own roots. Another method is *girdling the rootstock just above the graft union at the scion base*. The rootstock is girdled with budding rubber strips (0.016 gauge) (7). Budding rubbers disintegrate within a month when exposed to sun and air; however, when buried in the soil, they will last as long as 2 years, allowing sufficient time for the scion to become rooted. In a third method, an *incompatible rootstock is used*. When the graft is planted deeply, scion roots will gradually become more dominant in sustaining the plant. Examples of this are apple scions on pear rootstock, and lilac scions on ash rootstock.

**Figure 12-23**

Inlay bark graft. With Texas pecans, the scion of the inlay bark graft is stapled or nailed, and aluminum foil and a cut poly bag are used instead of grafting wax (40).

Approach Graftage

The distinguishing feature of approach grafting is that two independent, self-sustaining plants are grafted together. After a union has occurred, the top of the rootstock plant is removed above the graft, and the base of the scion plant is removed below the graft. Sometimes it is necessary to sever these parts gradually rather than all at once. Approach grafting provides a means of establishing a graft union between certain plants which are otherwise difficult to successfully graft. It is usually performed with one or both of the plants growing in a container. Rootstock plants in containers may also be placed adjoining an established plant that is to furnish the scion part of the new, grafted plant (Fig. 12-27, page 488).

This type of grafting should be done at times of the year when growth is active and rapid healing of the graft union will take place. Three useful methods of

making approach grafts are described as follows, and illustrated in Figure 12-28.

Spliced Approach Graft In the spliced approach graft, the two stems should be approximately the same size (Fig. 12-28, page 489). An exception to this is the spliced approach graft of mango in India, where the scion is considerably smaller than the field-grown rootstock; the scion, in a pot, is hung from the branch of the larger rootstock (19). At the point where the union is to occur, a slice of bark and wood 2.5 to 5 cm (1 to 2 in) long is cut from both stems. This cut should be the same size on each so that identical cambium patterns are made. The cuts must be perfectly smooth and as nearly flat as possible so that when they are pressed together there will be close contact of the vascular cambium layers. The two cut surfaces are bound tightly together with raffia or poly grafting tape, then the

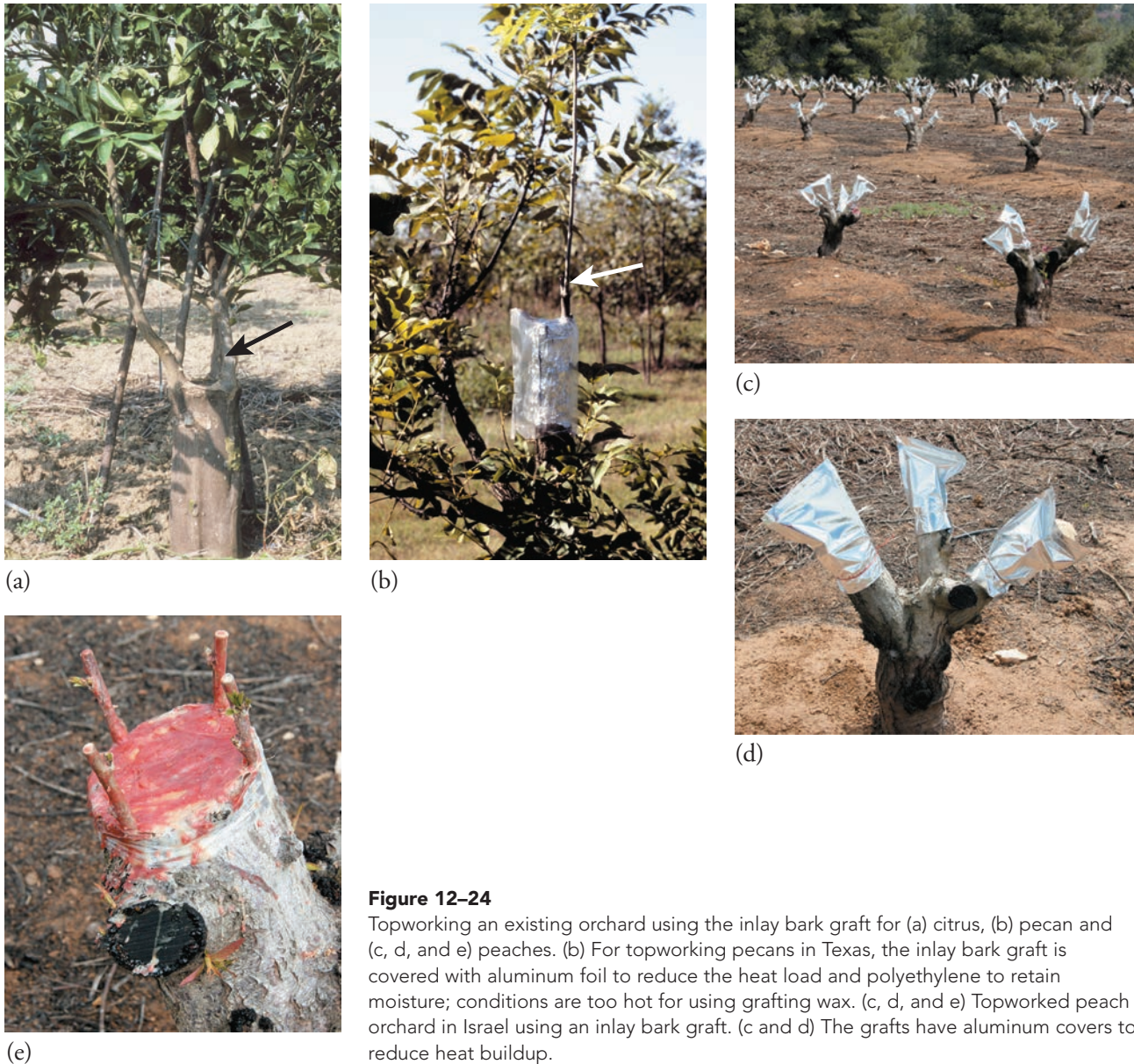


Figure 12-24

Topworking an existing orchard using the inlay bark graft for (a) citrus, (b) pecan and (c, d, and e) peaches. (b) For topworking pecans in Texas, the inlay bark graft is covered with aluminum foil to reduce the heat load and polyethylene to retain moisture; conditions are too hot for using grafting wax. (c, d, and e) Topworked peach orchard in Israel using an inlay bark graft. (c and d) The grafts have aluminum covers to reduce heat buildup.

whole union should be covered with grafting wax. After the parts are well united (which may require considerable time in some cases) the rootstock above the union, and the scion below the union are cut, and the graft is completed. It may be necessary to reduce the leaf area of the scion if it is more than the root system of the rootstock can initially sustain.

Tongued Approach Graft (TAG) The tongued approach graft is the same as the spliced approach graft, except that after the first cut is made in each stem to be joined, a second cut—downward on the stock and upward on the scion—is made, thus providing a thin tongue on each piece. By interlocking these tongues a very tight, closely fitting graft union can be obtained (Fig. 12-29, page 489).

For grafting vegetable crops, after the rootstock has fully developed cotyledons and scion has cotyledon and first true leaf, plants are pulled out from the tray (21). Make a cut at a 35- to 45-degree angle into the hypocotyl of the rootstock approximately halfway with a razor blade, and make a cut of the opposite angle on the hypocotyl of the scion. Cuts need to be made so that the scion will be on top of the rootstock when completed. Two cut hypocotyls are placed together and sealed with aluminum foil or Buddy Tape to help healing and prevent the graft from drying out. The two plants are transplanted into a bigger cell that will accommodate the two root balls. The top of the rootstock is cut off 5 days after grafting, and the bottom of the scion is cut off 7 days after the top of the rootstock is removed (Fig. 12-29).

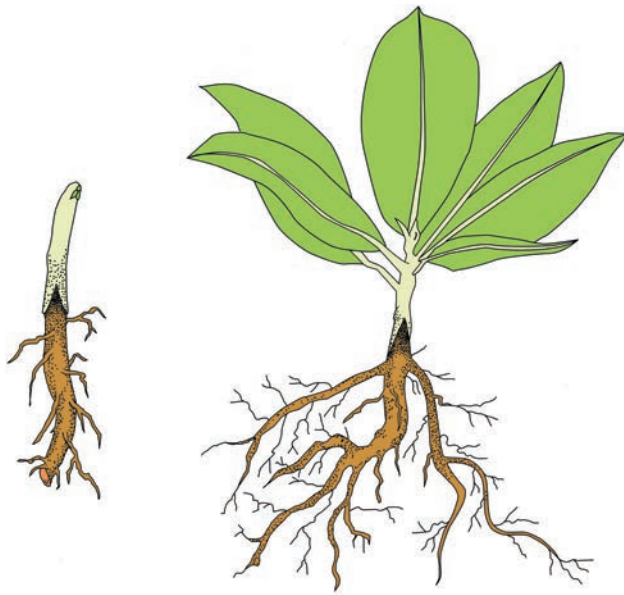


Figure 12-25

Root graftage with a saddle graft on a small root section or piece-root (*left*) and a whole root rootstock (*right*).

See Figure 12-3 which is a whip and tongue graft using a whole root apple rootstock.

Inlay Approach Graft The inlay approach graft may be used if the bark of the rootstock plant is considerably thicker than that of the scion plant. A narrow slot, 7.5 to 10 cm (3 to 4 in) long, is made in the bark of the rootstock plant by cutting two parallel channels and removing the strip of bark between (Fig. 12-28); this can be done only when the rootstock plant is actively growing and the bark “slipping.” The slot should be exactly as wide as the scion to be inserted. The stem of the scion plant, at the point of union, should be given a long, shallow cut along one side, of the same length as the slot in the rootstock plant and deep enough to go through the bark and slightly into the wood. This cut surface of the scion branch should be laid into the slot cut in the rootstock plant and held there by nailing with

two or more small, flat-headed wire nails. Then the entire union must be thoroughly covered with grafting wax. After the union has healed, the rootstock can be cut off above the graft and the scion below the graft.

Repair Graftage

Inarching Inarching is similar to approach grafting in that both rootstock and scion plants are on their own roots at the time of grafting. It differs in that the top of the new rootstock plant usually does not extend above the point of the graft union, as it does in approach grafting. Inarching is used to replace roots damaged by cultivation equipment, rodents, or disease. It can be used to very good advantage to save a valuable tree or improve its root system (Fig. 12-30, page 489).

Seedlings (or rooted cuttings) planted beside the damaged tree, or suckers arising near its base, are grafted into the trunk of the tree to provide a new root system to supplant the damaged roots. The seedlings to be inarched into the tree should be spaced about 13 to 15 cm (5 to 6 in) apart around the circumference of the tree if the damage is extensive. A damaged tree usually will stay alive for some time unless the injury is very severe. The procedure for inarching is to plant seedlings of a compatible species around the tree during the dormant season, and graft when active growth commences in early spring. Inarching may also enhance growth of uninjured, older trees (22).

As illustrated in Figures 12-30 and 12-31 (page 490), the graft is similar to an inlay bark graft. The upper end of the seedling, which should be 6 to 13 mm (1/4 to 1/2 in) thick, is cut shallowly along the side for 10 to 15 cm (4 to 6 in). This cut should be on the side next to the trunk of the tree and deep enough to remove some of the wood, exposing two strips of cambium tissue. Another, shorter cut, about 13 mm (1/2 in) long, is made on the side opposite the long cut, creating a sharp, wedge-shaped end on the seedling stem.

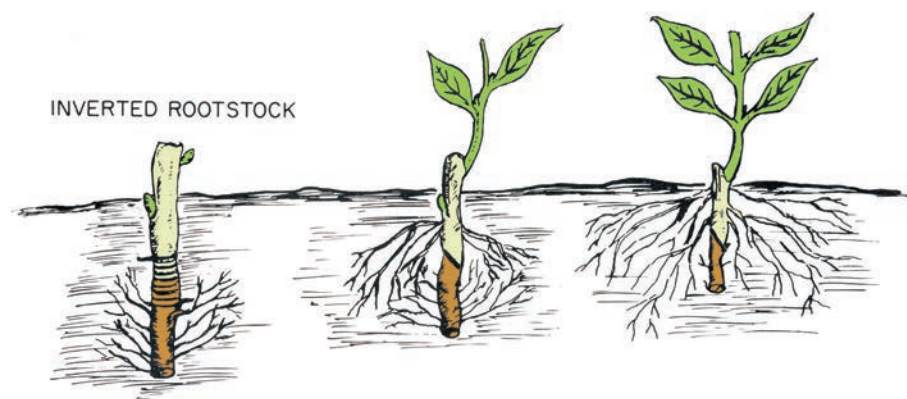
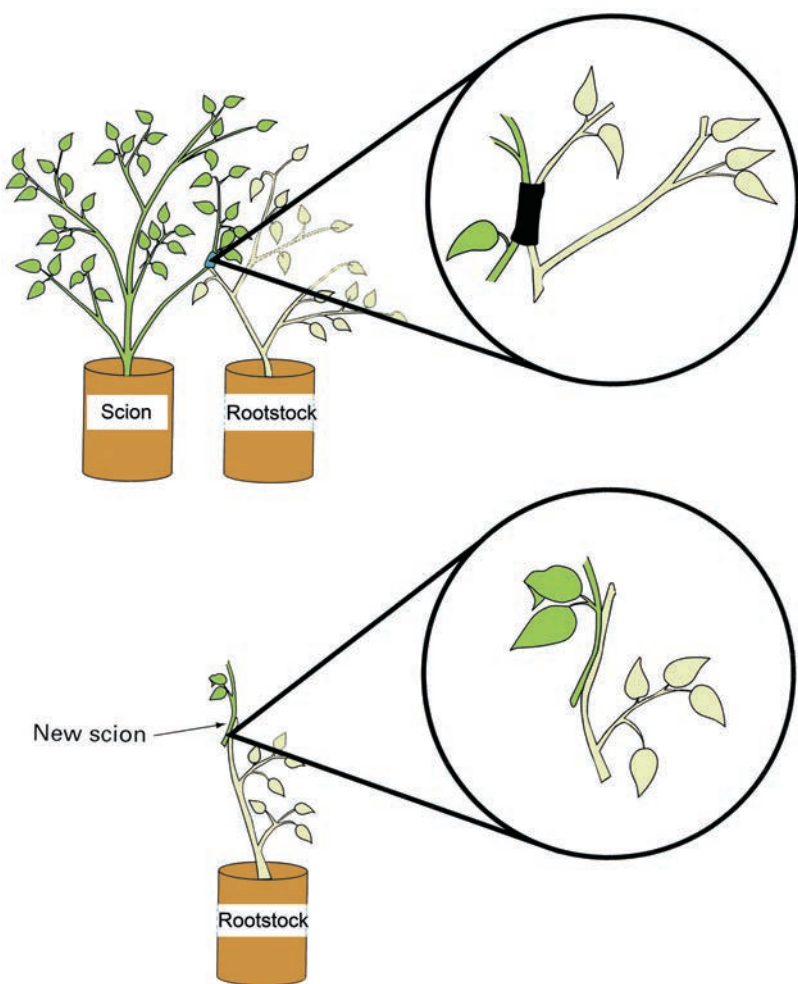


Figure 12-26

Reversing the polarity of the rootstock piece of the root graft is one method of “nurse-root” grafting. The nurseroot graft is a temporary graft used to induce the scion to develop its own roots. The nurse root sustains the plant until the scion roots form, then it dies. In the method shown, the rootstock piece is inverted, so the distal of the rootstock is temporarily joined to the proximal of the scion.

**Figure 12-27**

Approach grafting. *Top:* Initial grafting of the containerized scion and rootstock plants. *Below:* Completed graft union with scion severed from its own roots, and shoots of rootstock severed above the graft union.

A long slot is cut in the trunk of the tree by removing a piece of bark the width of the seedling and just as long as the cut surface made on the seedling. A small flap of bark is left at the upper end of the slot, under which the wedge end of the seedling is inserted. The seedling is nailed into the slot with four or five small, flat-headed wire nails. The nail at the top of the slot should go through the flap of bark and through the end of the seedling. If the bark of the tree along the sides of the seedling is accidentally pulled loose, it should be nailed back into place. The entire area of the graft union should then be thoroughly waxed.

Bridge Grafting Bridge grafting is another form of repair grafting—used when there is injury to the trunk, such as by cultivation equipment, rodents, disease, or winter injury. If the damage to the bark is extensive, the tree is almost certain to die, because the roots will be deprived of their carbohydrate supply from the top of the tree. Trees of some species, such as the elm, cherry, and pecan, can compartmentalize extensively injured areas by the development of a

wound periderm of callus tissue. However, most woody species with severely damaged bark should be bridge grafted if they are to be saved, as illustrated in Figure 12-32, page 491.

An *interstock bridge graft system* has been used with mature apple trees for grafting M9 dwarfing rootstock (as the interstock) onto semi-dwarfing apple rootstock, leading to 20 percent reduced shoot growth, but a 30 percent increase in yield and increased soluble sugars and starch in the scion (53). A ring of bark 8 cm wide was removed from the trunk about 30 cm from ground level. Bridge grafts composed of 1-cm-wide split interstocks were inserted perpendicular around the ring, and then tightly wrapped with plastic during graft healing (New Zealand).

Bridge grafting is best performed in early spring as active growth of the tree is beginning and the bark is slipping easily. The scions should be obtained when dormant from 1-year-old growth, 6 to 13 mm (1/4 to 1/2 in) in diameter, of the same or compatible species, and refrigerated until grafted. In an emergency, one

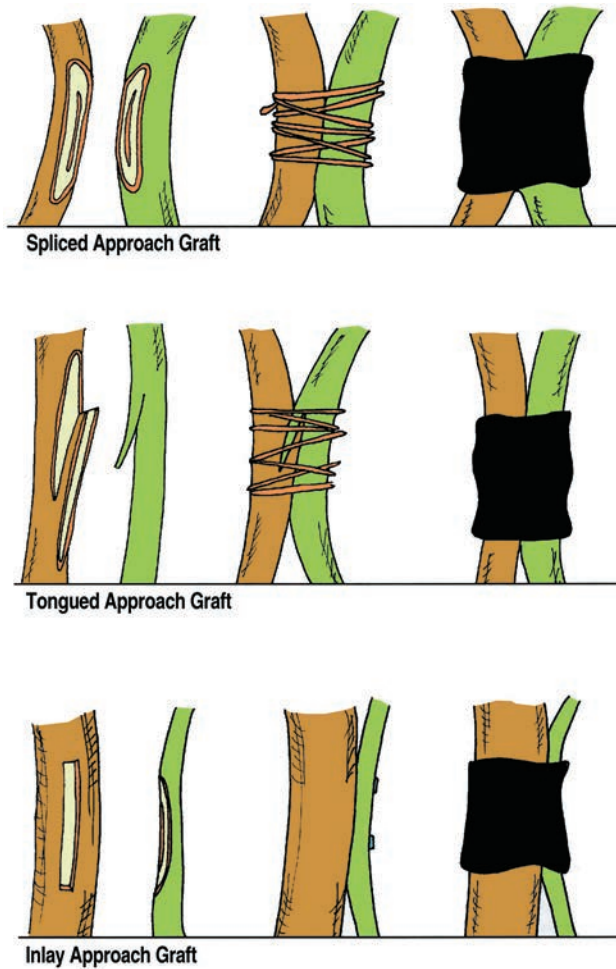


Figure 12-28
Three methods of making an approach graft: spliced-,
tongued- and inlay-approach graft.

may successfully perform bridge grafting late in the spring, using scionwood whose buds have already started to grow; the developing buds or new shoots are removed.

The first step in bridge grafting is to trim the wounded area back to healthy, undamaged tissue by removing dead or torn bark. A scion is inserted every 5 to 7.5 cm (2 to 3 in) around the injured section and attached at both the upper and lower ends into live, undamaged bark. It is important that the scions are right side up. If reversed, a union may form, but the scions will not enlarge in diameter as they would if inserted correctly. Figure 12-33, page 491 shows the details of making a bridge graft.

After all the scions have been inserted, the cut surfaces must be thoroughly covered with grafting wax; particular care should be taken to work the wax around the scions, especially at the graft unions.

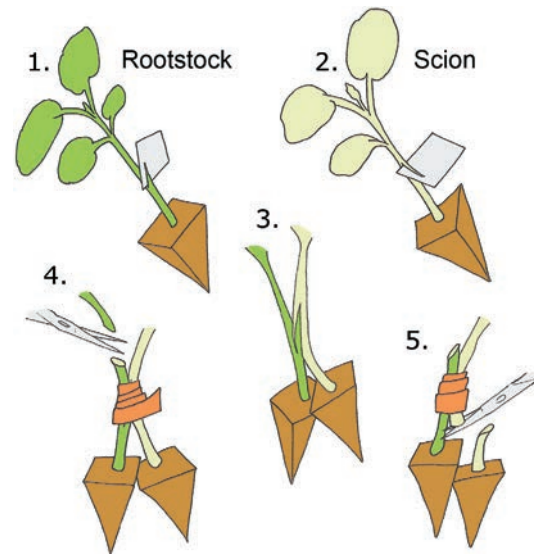


Figure 12-29
Tongued Approach Graft (TAG) with cucurbits. An easy graft that requires no special equipment or graft healing chambers, has a high success rate, but is labor intensive (12, 21). Illustrations courtesy R. L. Hassell.

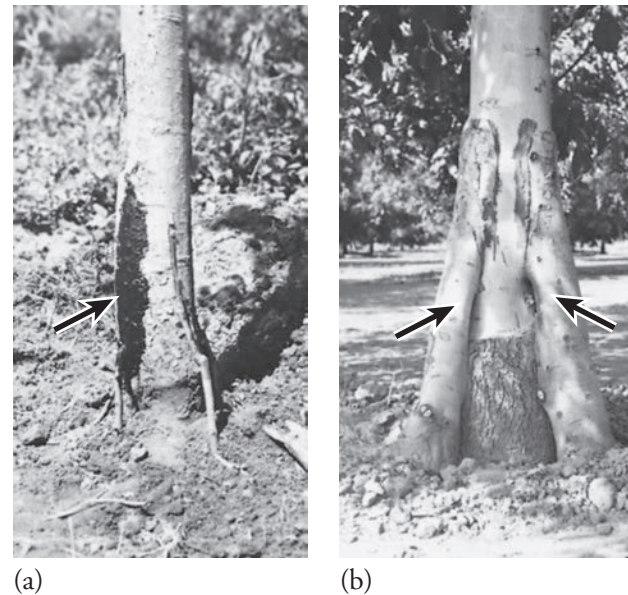


Figure 12-30
(a) Inarches that have just been inserted (arrows). The one on the left has been waxed. The one on the right has been nailed into place and is ready for waxing. (b) Inarching can be used for invigorating established trees by replacing a weak rootstock with a more vigorous one. Here a Persian walnut tree has been inarched with Paradox hybrid seedlings (*Juglans hindsii* × *J. regia*).

Bracing Bracing is a form of natural branch grafting that is used by fruit producers to strengthen scaffolding limbs of a tree in order to support the weight of the fruit crop. Natural grafting of roots or shoot systems occurs in species such as fig (*Ficus*), rubber trees

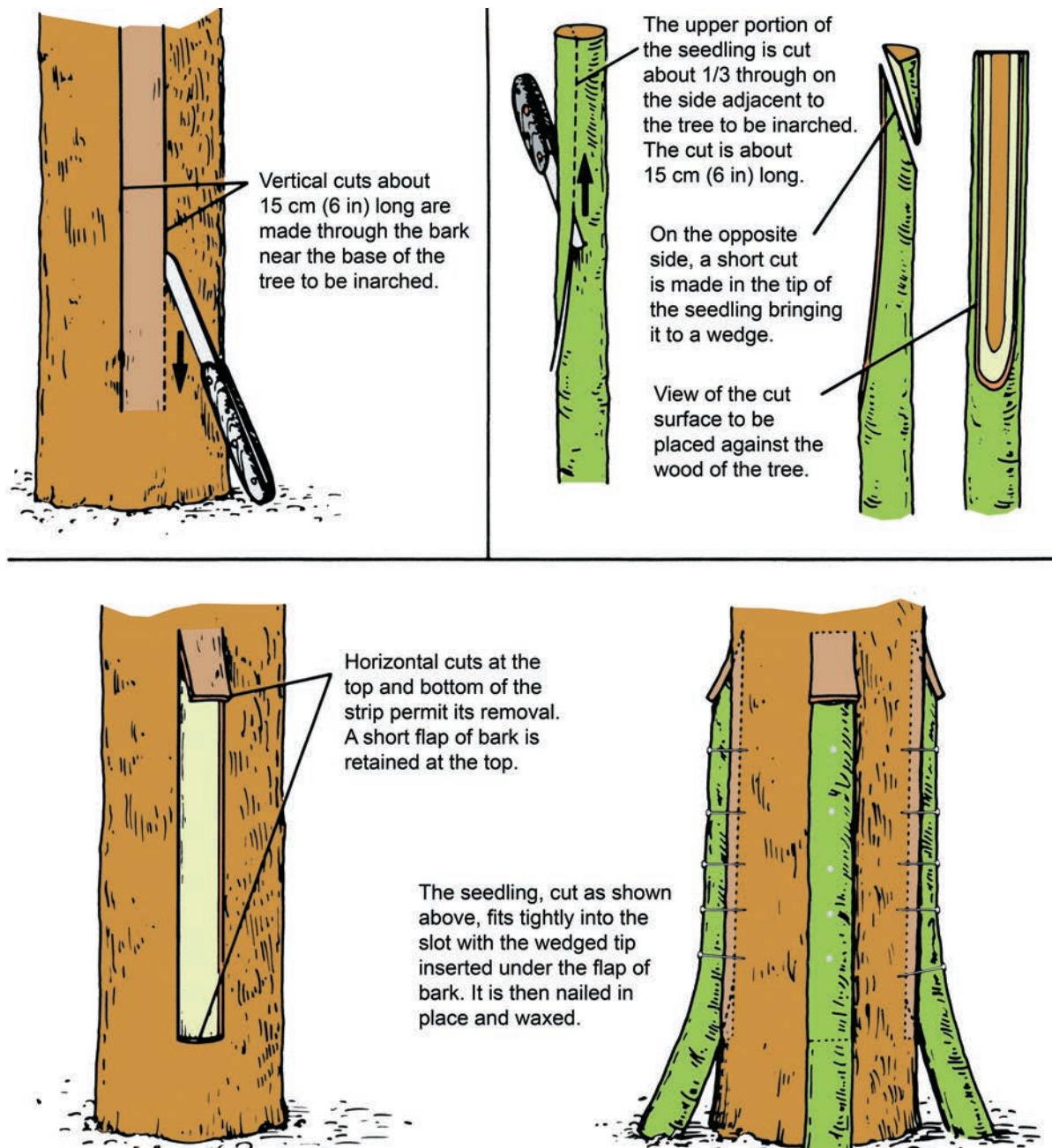


Figure 12-31

Steps in inarching a large plant, with smaller ones planted around its base.

(*Hevea*), birch (*Betula*), beech (*Fagus*), ash (*Fraxinus*), maple (*Acer*), pine (*Pinus*), and climbing species such as English ivy (*Hedera*) (see Chapter 11). Branches and trunks can naturally graft when they come in contact with each other during early development. The union begins with compression and constant and increasing pressure that ruptures the outer bark of the graft partners, followed by continued secondary growth, which

leads to graft union formation and the joining of the independent vascular systems of the partners.

When bracing limbs, fruit producers will pull together two strong, young lateral shoots from the limbs to be braced. A rope or cord is used to temporarily brace the larger limbs. The weaved smaller shoots, which will naturally graft, are tied with waxed string or poly tape to keep them together (Fig. 12-34, page 492).

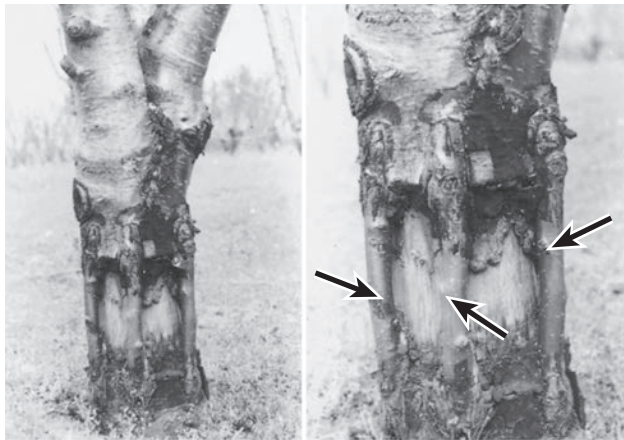


Figure 12-32
Injured trunk of a cherry tree successfully bridge grafted (arrows) by a modification of the bark graft.

PRODUCTION PROCESSES OF GRAFTAGE

Success in grafting depends 45 percent on preparation, including the quality and preparation of the scion and rootstock material, 10 percent on craftsmanship, and 45 percent on the aftercare of the grafted plant (26, 38). The production goals of grafting are achieving a high success rate, or “take,” and obtaining high speed and accuracy in performing the graft. Preparation for grafting begins with the proper tools and accessories, as well as the selection and handling of the scion and rootstock (Table 12-3). Since grafting is a repetitive, labor-intensive process, grafting machines and grafting automation, including robotics, continue to play a greater role.

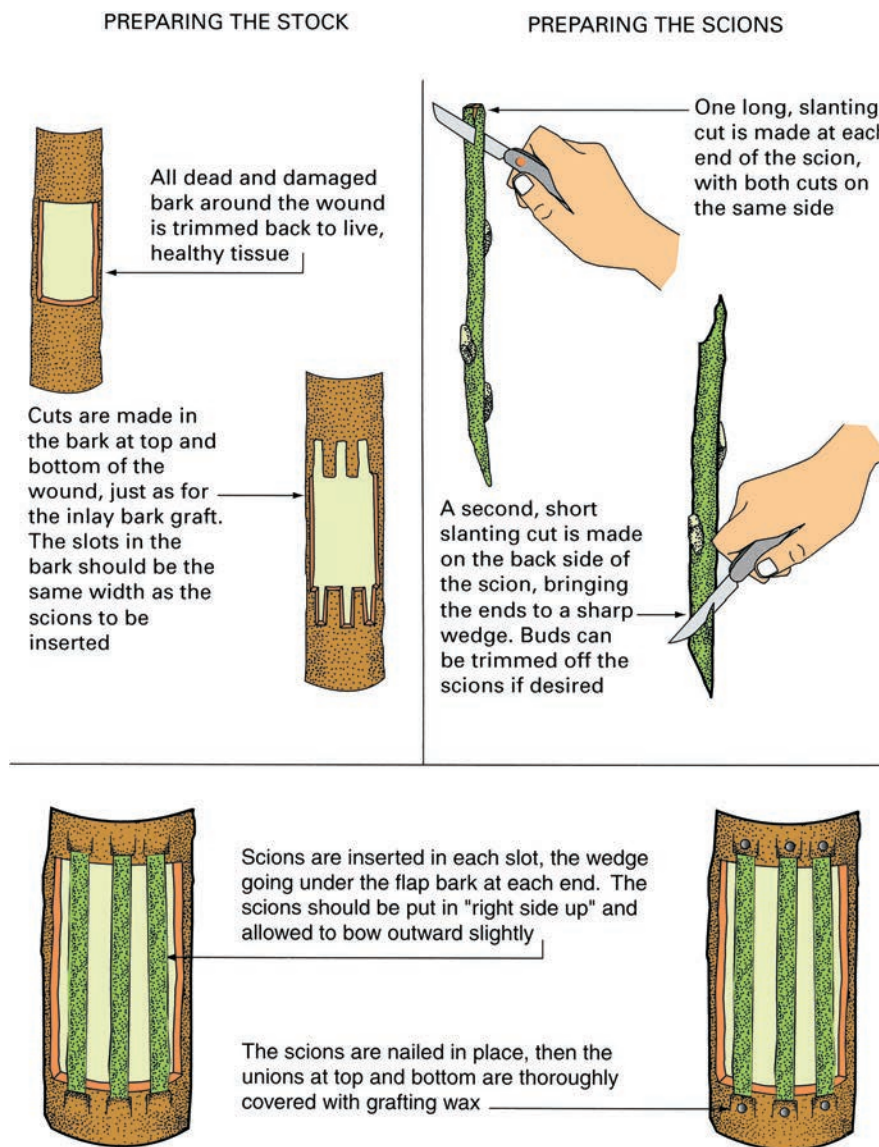


Figure 12-33
A satisfactory method of making a bridge graft, using a modification of the inlay bark graft.



BOX 12.2 GETTING MORE IN DEPTH ON THE SUBJECT LARGE-SCALE BRIDGE GRAFTING



After World War I, thousands of fruit trees were bridge grafted in France to repair damage that occurred during the

war. Alternatively, trunks from mutilated trees less than 20 cm (8 in) in diameter were cut off and crown grafted (23).

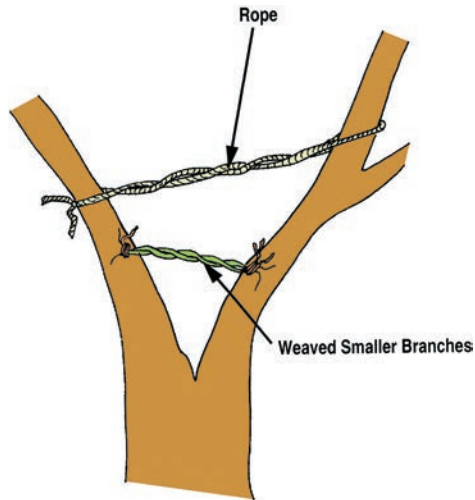


Figure 12-34

Bracing of fruit tree limbs by encouraging natural grafting. The tree limbs are braced with a twisted rope or electrical cord, and smaller shoots from the limbs are woven together and graft naturally as secondary growth occurs.

Preparation for Grafting

Tools and Accessories for Grafting Common tools and accessories used for grafting include grafting knives, tying and wrapping materials, and grafting waxes. Special equipment needed for any particular

method of grafting is illustrated, along with the description of the method, in the remaining pages of this chapter. For example, grafting planes are sometimes used for more accurate fitting of scions with a hard and thick wood (Fig. 12-35) (61).

Knives. The two general types of knives used for propagation work are the budding knife and the grafting knife (Fig. 12-36). Where a limited amount of either budding or grafting is done, the budding knife can be used satisfactorily for both operations. The knives have either a folding or a fixed blade. The fixed-blade type is stronger, and if a holder of some kind is used to protect the cutting edge, it is probably the most desirable. A well-built, sturdy knife of high-carbon steel is essential. Grafting blades are flat on one side and have a tapered edge on the other to make a sharp, clean cut. Grafting knives are available for either right- or left-handed people.

Tying and Wrapping Materials. Grafting methods, such as the whip-and-tongue, splice (whip), and side-veneer graft, and budding methods, such as chip budding and T-budding, require that the graft union be held together by tying until the parts unite. A number of materials can be used for tying or wrapping grafts and budding. Some of these tying materials can also seal and help maintain a high relative humidity in the graft union area, which can help eliminate production

Table 12-3
PRODUCTION PROCESSES OF GRAFTAGE

Preparation for Graftage

- Tools and accessories for grafting
- Grafting machines and grafting automation/robotics
- Selection, handling, and storage of scionwood
- Handling of rootstock.

The Craftsmanship of Grafting

- Manual techniques: speed, accuracy, enhancing success rates
- Record keeping

Aftercare of Grafted Plants

- In bench grafting systems
- In field and nursery grafting systems

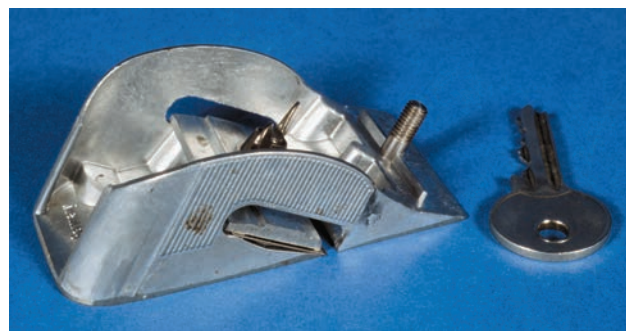


Figure 12-35

The grafting plane is a small woodworking plane equipped with a disposable heavy-duty razor blade. It allows more precise fitting of scions with hard and thick wood (61).

**Figure 12-36**

Folding, budding-grafting knives. (a) Tina budding-grafting knife. (a, b, and c) The metal flap (arrow) opposite the sharp end of the blade is used to separate the bark during the “T”-cut of the rootstock. (b) The quill is also used to separate the bark during T-budding. (d) Grafting knives are sharpened on one side, so there is a flat side of the blade for better control.

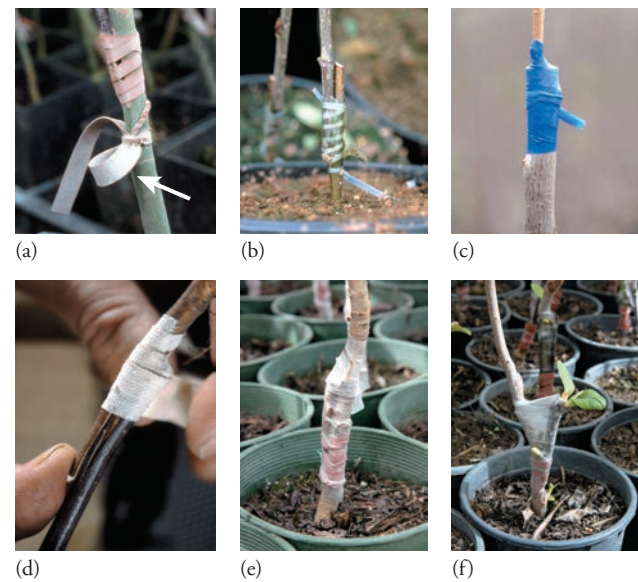
steps for applying a hot wax sealant on top of the tying materials, or the need for maintaining the grafts in special poly chambers or “sweat boxes.”

Some common tying materials for budding and grafting include:

- **Budding rubbers** (also used in grafting).
- Clear or colored polyethylene or polyvinyl chloride (PVC) **budding and grafting strips**, which are 0.5 to 1.3 cm (3/16 to 1/2 in) wide and slightly elastic, allowing for a more secure wrap; this is also called flagging tape, green floral tape, white budding tape, or orange grafting tape.
- **Plastic clips and silicon tubing** (for manual and robotic grafting).
- **Raffia** (strips of palm leafstalk fiber—an older wrapping material, but still used).

Since PVC budding and grafting strips are not self-adhesive, they must be tied with a half-hitch knot (Fig. 12-37), which is done at the final turn of the tape by slipping it under the previous turn. With the exception of budding rubber, which deteriorates in full sunlight (but not when buried with the graft below ground), or Buddy Tape, the wrapping materials must be removed later to prevent girdling the plant.

Self-Adhering Tying Materials. A time-tested tying material is **waxed string** or **twine**, which adheres to

**Figure 12-37**

(a) Sometimes a loop is included in the final half-hitch knot of the rubber (arrow) or polyethylene budding and grafting strips. This allows easy unraveling of the strips after the graft has “taken” and avoids potential girdling problems in this side veneer graft of Japanese maple. Various tying materials: (b) raffia, (c) poly tape, (d) nursery tape, and (e and f) Buddy Tape (similar to Parafilm) used to cover magnolia scion pieces.

itself and to the plant parts without tying. It should be strong enough to hold the grafted parts together, yet weak enough to be broken by hand.



Nursery adhesive tape is similar to surgical adhesive tape but lighter in weight and not sterilized; it is more convenient to use than waxed cloth tape. Adhesive tape is useful for tying and sealing whip grafts. When using any kind of tape or string for wrapping grafts, it is important not to use too many layers or the material may eventually girdle the plant unless it is cut. When this type of wrapping is covered with soil, it usually rots and breaks before damage can occur. On a limited scale, adhesive tapes, such as **duct** and **electrical tape** can be used, while **masking tape** tends to unravel (54). Regardless of the wrapping material, it is best to remove or cut it *after* the graft has taken to avoid girdling.

Self-sealing tying materials include **Parafilm tape**, which has been used with successful results to wrap graft unions rapidly (5) and for chip-budding roses (Fig. 13–6). This material is a waterproof, flexible, stretchable, thermoplastic film with a paper backing. The film is removed from the paper, wrapped around the graft union, and pressed into place by hand. **Buddy Tape** (buddytape.com) is similar to Parafilm tape, but thinner and more economical. It seals and holds the graft or bud piece in place, and is thin enough for the bud to elongate and pass through it once the graft “takes” (Fig. 12–37). Sometimes budding rubbers are used to tie a graft, which is then sealed with Parafilm tape. Self-sealing cure **crepe rubber sheets** are used for herbaceous grafts and small woody plant material. Rubber patches up to 4 cm (1 1/2 in) are fixed with a staple and used for budding (Fig. 12–38).

Miscellaneous Fastenings and Wrapping Material. Miscellaneous fastenings and wrapping material include 18-gauge, 2-cm (3/4-in) **nails**, 1.6-cm (5/8-in) **flat-point staples**, as used in the inlay bark graft of pecans (40), and **plastic graft clips**, used in manual and machine splice grafting of vegetable crops (Figs. 12–7 and 12–39). The combination of **aluminum foil** and **polyethylene bags** wrapped around a four-flap or inlay bark graft replaces the need for waxing the graft (which would melt and be unsuitable in spring field grafting in Texas or other warm regions) (Figs. 12–13 and 12–24). **Metal shoot guide clips** (Fig. 13–4) are used for field budded, dormant rootstock to compel upright growth from the bud. **Silicon tubing** has been used to hold graft unions of single-node scions of oak and ash with high rooting success (Fig. 12–40, page 496) (14).

Splints made of *toothpicks*, *bamboo*, or *metal skewers* are used with bench grafting of herbaceous plants such as cacti. The splints are later removed after the graft has taken.

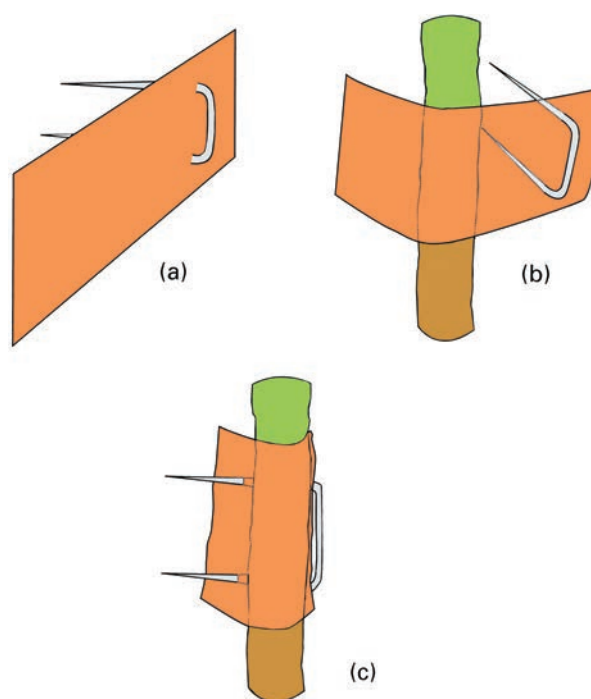


Figure 12–38

Rubber patch tying materials: (a) Rubber patches that come with a fixed stainless steel staple. (b) The rubber sheet is pulled over the bud and pulled securely around the rootstock. (c) The staple is pushed through the flap to secure the patch. The rubber patch normally deteriorates later with UV light from the sun or can easily be removed.

In a novel approach for developing robotic grafting systems for vegetable crops in Japan, Chinese cabbage seedling (scions) are horizontally grafted to turnip rootstocks. In grafting *Solanaceae* and *Cucurbitaceae* vegetable crops, the graft partners are joined by a chemical adhesive, followed by spraying a chemical hardener to set up and solidify the adhesive around the graft (see Fig. 12–43, page 498 (29, 34, 47, 48)).

Whether a sealant, such as grafting wax, may be applied depends on the type of graft, the grafting system, and type of material used. Sealants are generally not used with budding, since tying with budding rubbers, rubber patches, Buddy Tape, or Parafilm tape is sufficient to alleviate desiccation problems. If the bench-grafted plant is to be placed in a high relative humidity graft box or temperature-controlled polytent, or immediately outplanted in the field with the union below the soil surface, waxing may be omitted.

Grafting Waxes. Grafting wax has two chief purposes: (a) It seals over the graft union, thereby preventing the

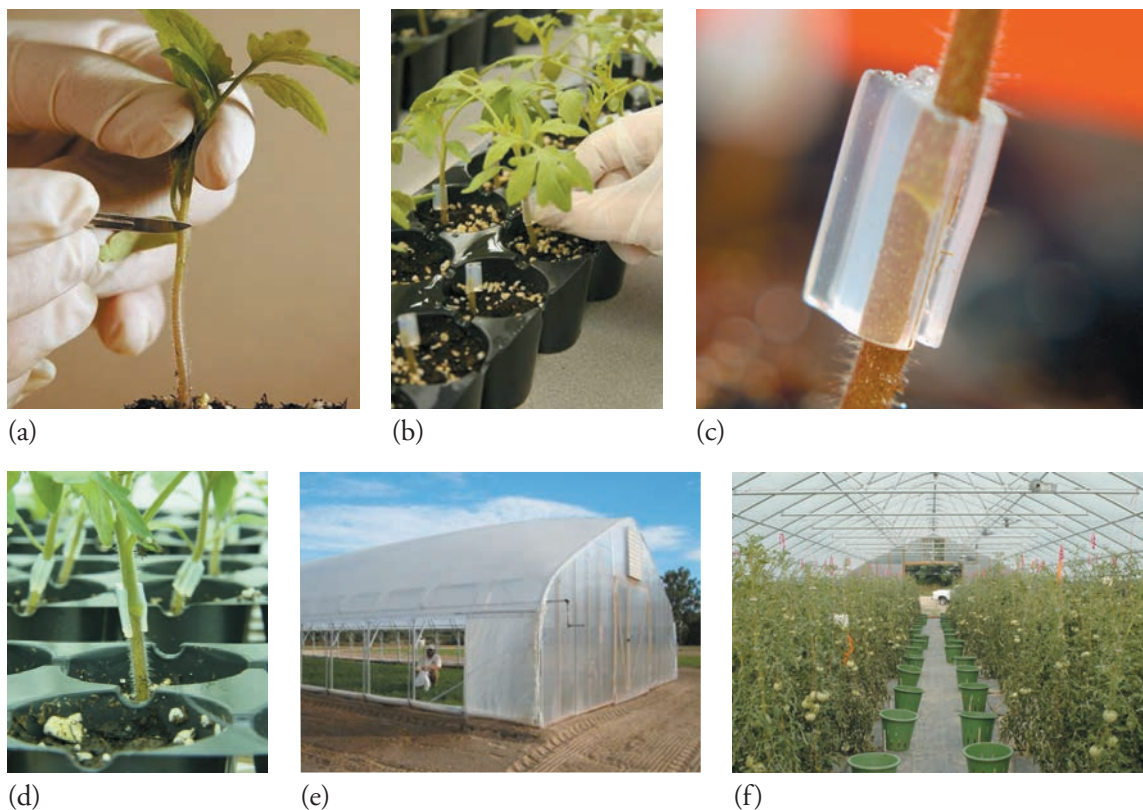


Figure 12-39

Grafting of heirloom tomatoes in high tunnels can lead to increased yield, earlier season extension (compared to field-grown), soil-borne disease resistance and increased nutrient uptake with a potential reduction in fertilizer inputs. (a, b, c, and d) OCG or Japanese tubegrafting system. (c and d) Plastic clip holding graft. (e and f) High tunnel production of grafted heirloom tomatoes. The system enhances IPM—integrated pest management—and organic production systems for vegetable crops (52).

Photos courtesy S. O'Connell, M. Peet, C. Rivard, F. Louws, and S. McDonough.

loss of moisture and death of the tender, exposed cells of the cut surfaces of the scion and rootstock. These cells are essential for callus production and healing of the graft union. (b) It prevents the entrance of various decay-producing organisms that rot wood.

An ideal grafting wax should adhere well to the plant surfaces, not be washed off by rains, not be so brittle as to crack and chip during cold weather or so soft that it will melt and run off during hot days, but

hot waxes Waxes that are paraffin based and must be heated to melt and apply.

cold waxes Waxes that contain a volatile solvent that preserves the wax liquid. After application the solvents evaporate and the wax hardens.

still be pliable enough to allow for the swelling of the scion and the growth enlargement of the rootstock without cracking. **Hot waxes** require heating, while **cold waxes** contain volatile solvents that keep the wax liquid. The cold wax solidifies

when the solvents evaporate. Most nurseries develop their own hot wax, which is low-melting, soft, and flexible, so that subsequent handling of the graft does not cause cracking and flaking. Thermostatically controlled wax heaters are available to provide instant liquid wax when needed. *The wax should be hot enough to flow easily, yet not be boiling, which damages plant tissue.*

Various recipes for making hot and cold waxes are listed by Garner (19). For hot wax, blocks of premixed grafting wax containing the necessary ingredients (e.g., TrowBridge's grafting wax, Walter E. Clark & Son, Orange, Conn., USA) can be purchased from nursery supply houses.

Grafting Machines Several *bench grafting* machines or devices have been developed to prepare graft and bud unions, and a few have been widely used, especially in propagating grapevines (2, 3).

Various bench grafting machines for the wedge graft or French-V are available, including a portable and

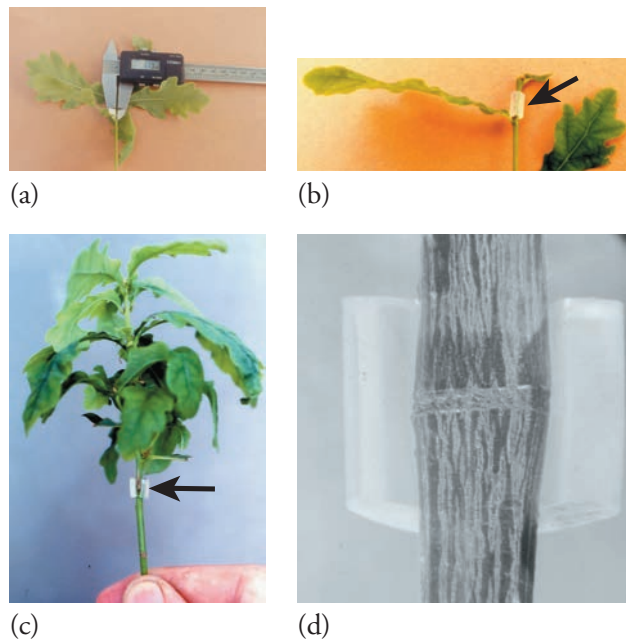


Figure 12-40

High grafting success has been obtained using silicone tubing to hold graft unions together of single-node scions of oak and ash: (a) Digital caliper to measure stem diameter. (b) Single node of oak grafted using silicone tube (arrow). (c) Oak graft after 8 weeks (arrow showing tubing). (d) Healed ash graft after 12 weeks. Photographs courtesy of G. Douglas (14).

bench-mountable device made in New Zealand by Raggett Industries, Ltd., Gisborne (www.raggettindustries.co.nz) (Fig. 12-41). This device makes a type of wedge graft, cutting out a long V-notch in the rootstock and a corresponding long, tapered cut at the base of the scion. By reversing the position of the rootstock and scion, it could also make a saddle graft (Fig. 12-11). Although the cuts fit together very well, the operation is slow because the graft union must be either tied with a budding rubber or poly tape or stapled together. This machine has been used successfully in propagating grapes and fruit trees.

There are machines for making omega grafts, which are hand-operated (Fig. 12-42) or foot-operated. One device for grape grafting is the Ppropf-Star grafting machine manufactured in Germany. It cuts through both the rootstock and scion, one laid on top of the other, making an omega-shaped cut and leaving the two parts interlocked. While these machines work fine for grape grafting, most ornamental nurseries that graft do not use machines. Instead, they rely on hand-grafting, which may be faster and more reliable given the larger number of genera and species grafted (35). Without question, finding

skilled grafters is a severe production problem; hence the importance of developing mechanized and automated grafting systems.

Grafting Automation/Robotics Prototypes and commercial robotic machines for grafting vegetable seedlings have been developed (Figs. 12-43, 12-44, and 12-45, pages 498-99). The production of grafted vegetable crops is becoming more common in the United States. However, grafted vegetable seedlings are used extensively in heavily populated countries such as Japan, Korea, some other Asian countries, and in parts of Europe, where the land use is highly intensive, farming areas quite small, and crops are not rotated. Grafted seedlings account for 81 percent of the commercial outdoor and greenhouse vegetable production in Korea, and 54 percent and 81 percent, respectively, for Japan (12, 29, 30, 33). Vegetable rootstock used are resistant to soil-borne pathogens and nematodes, which build up under these intensive cultivation conditions. Some of the commercialized grafting robots can graft 800 or more *Solanaceae* vegetable seedlings per hour (Figs. 12-43 and 12-45) (49).

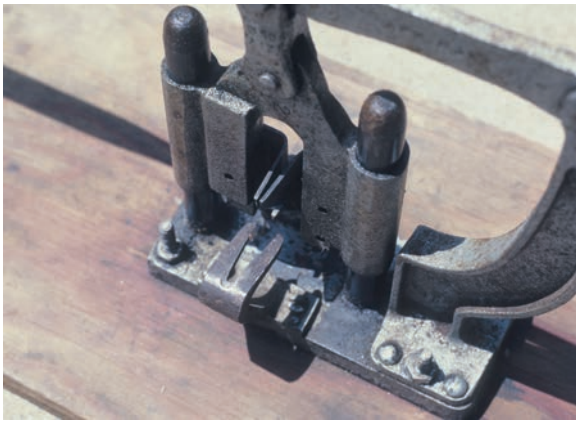


Selection, Handling, and Storage of Scionwood.

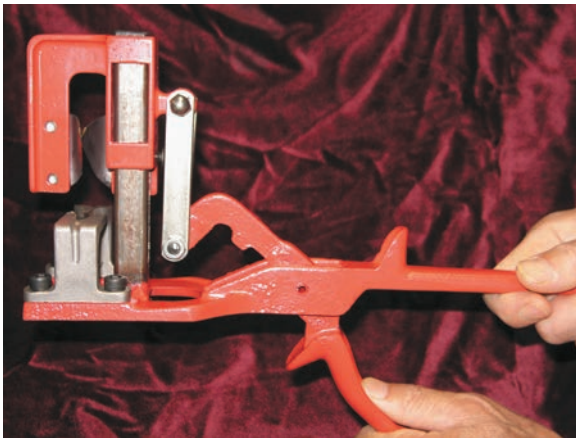
Kind of Wood. Since bench or field grafting of deciduous species takes place in winter or early spring, it is necessary to use the scionwood that grew the previous fall.

In selecting such scion material the following points should be observed:

- For most species, the wood should be 1 year old or less (current season's growth). Avoid including older growth, although with certain species, such as the fig or olive, 2-year-old wood is satisfactory, or even preferable, if it is of the proper size.
- Healthy, well-developed vegetative buds should be present. Avoid wood with flower buds. Usually, vegetative buds are narrow and pointed, whereas flower buds are round and plump (see Fig. 13-3).
- The best type of scion material is vigorous (but not overly succulent), well-matured, hardened shoots from the upper part of the tree, which have grown 60 to 90 cm (2 to 3 ft) the previous summer. Such growth develops on relatively young, well-grown, vigorous plants; high production of scion material can be promoted by pruning the plant back heavily the previous winter. Water sprouts from older trees sometimes make satisfactory scionwood, but suckers arising from the base of grafted trees should not be used, since they



(a)



(b)



(c)

Figure 12-41

(a and b) Wedge grafting made by French-V grafting devices. (b) Raggett top grafter. (c) Grape graft union healing with profuse callusing (arrow) one month after bench grafting with a wedge graft or French-V. Grafts can be made with these devices much faster than by the whip-and-tongue graft method. These machines can also make a saddle graft by these machines, by reversing the cuts so the scion piece has the saddle shape (see Fig. 12-11).



(a)



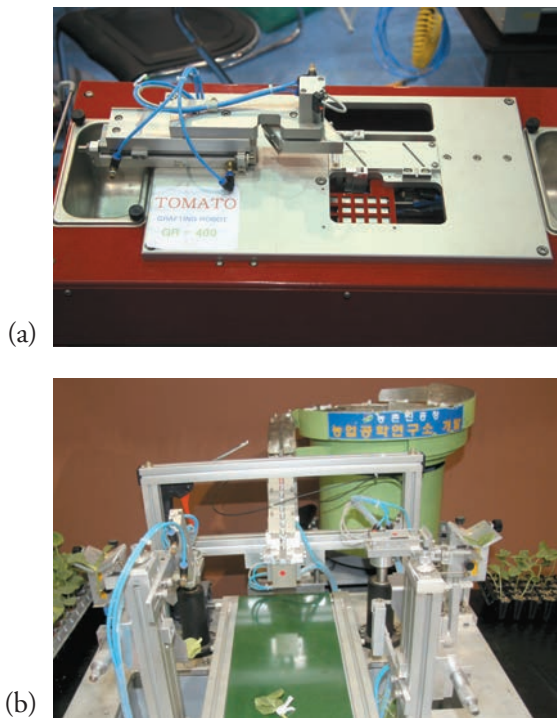
(b)



(c)

Figure 12-42

(a) Grafting tool for making an omega graft. (b and c) Omega graft locks in place and then is held together with grafting tape. The scion and stock must be the same diameter.

**Figure 12-43**

Commercial grafting robot for Solanaceae (tomatoes, melons, cucurbits) vegetables on seedling rootstock suitable for intensive planting and resistant to disease, insect and environmental stress. Plant vigor and yield can also be enhanced with superior rootstock. (a) Tomato and (b) melon grafting robots.

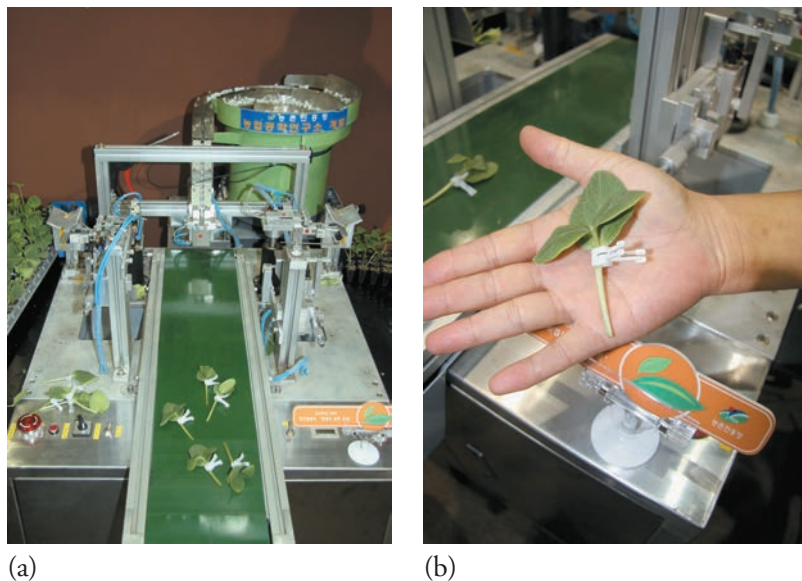
may consist of rootstock material. A satisfactory size is from 0.6 to 1.2 cm (1/4 to 1/2 in) in diameter.

- The best scions are obtained from the center portion or from the basal two-thirds of the shoots. The terminal sections, which are likely to be too succulent,

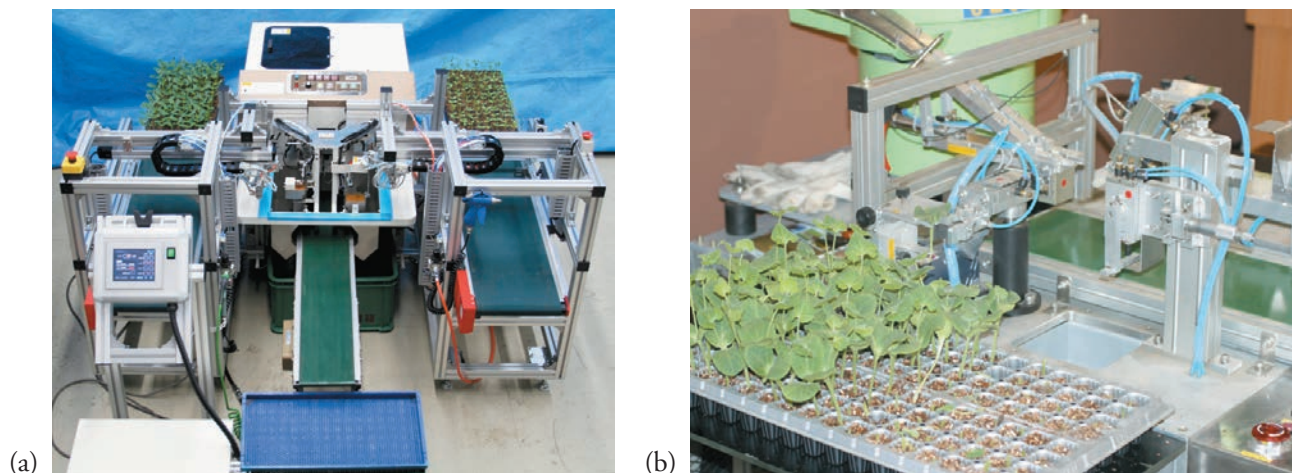
pithy, and low in stored carbohydrates, should be discarded. Mature wood with short internodes should be selected.

Source of Material. Scionwood should be taken from source plants of the correct cultivar known to be pathogen-tested and genetically true-to-type (see Chapter 16). Virus-diseased, undesirable sports, chimeras, and virus-like genetic disorders must be avoided. Source plants may be of three basic types:

1. Plants produced in an orchard, vineyard, ornamental field, container nursery, or landscape are selected when the flowering, fruiting, and growth habits are known. It is best to take propagation material from bearing plants whose production history is known. Visual inspection, however, may not reveal the true condition of the proposed source plant and, appropriate indexing and progeny tests are required to be sure (see Chapter 16).
2. In commercial nurseries, special scion blocks, where plants are grown particularly for propagation, may be maintained. Such plants are handled differently than they would be for producing a crop. For example, fruit trees may be pruned back each year to produce a large annual supply of long, vigorous shoots well-suited for scionwood. Such special blocks would usually be handled to conform to registration and certification programs and would be subject to isolation, indexing, and inspection requirements. In addition, it is important to maintain source identity of scion material through the entire propagation sequence, so that over a period of time proper

**Figure 12-44**

Finished grafts from a commercial melon grafting robot. (a) The grafted plants are moved on a conveyor belt system for processing. (b) Splice grafted scion and rootstock held together by a grafting clip.

**Figure 12-45**

Two techniques used in herbaceous grafting are manual and robotic grafting. (a) Fully automated grafting robot for cucurbits (BRAIN, Saitama, Japan), and (b) semiautomated Korean grafting machine. Plants are grafted at the 2 to 4 leaf stage. The advent of OCG, “tube-grafting” or “Japanese top-grafting” has become the most popular graft for tomato. Grafting robots can make up to 800 grafts/hr, whereas an individual can make 1,000 grafts/day. Photos a and b courtesy of C. Kubota and M. Peet, respectively.

sources of the various cultivars can be identified and maintained.

- For vegetable grafting, commercial seed from selected rootstocks and scions are sown under protected cultural conditions. Selected rootstock for vegetable grafting is listed in Table 12-4. A timeline for grafting heirloom tomatoes, starting with sowing rootstock seed 2 to 5 days prior to sowing scion seed, is depicted in Figure 12-46.

Collection and Handling. For deciduous plants to be grafted in early spring, the scionwood can be collected almost any time during the winter season when the plants are fully dormant (6). In climates with severe winters, the wood should not be gathered when it is

frozen, and any wood that shows freezing injury should not be used. Where considerable winter injury is likely, it is best to collect dormant scionwood and put it in cold storage after leaf fall but before the onset of winter.

Storage. Scionwood collected prior to grafting must be properly stored. It should be kept slightly moist and at a low enough temperature to prevent elongation of the buds. A common method is to wrap the wood, in bundles of 25 to 100 sticks, in heavy, waterproof paper or in polyethylene sheets or bags. *All bundles must be labeled accurately.*

Polyethylene bags are useful for storing small quantities of scionwood. They allow the passage of oxygen and carbon dioxide, which are exchanged during

Table 12-4
SELECTED SCION AND ROOTSTOCK COMBINATIONS FOR VEGETABLE GRAFTING (50)

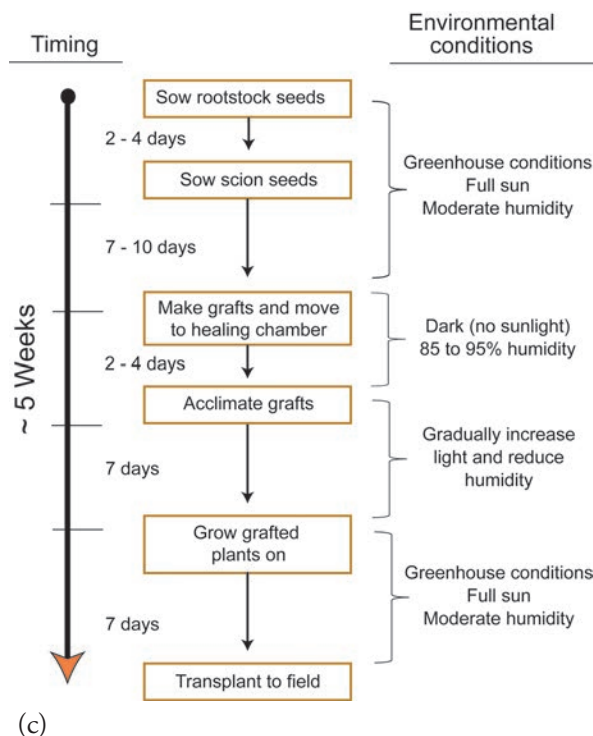
Scion	Rootstock
Watermelon (<i>Citrullus vulgaris</i> syn. <i>C. lanatus</i>)	Bottle gourd (<i>Lagenaria siceraria</i>) White gourd (<i>Benincasa hispida</i>) <i>Cucurbita</i> spp.
Melon (<i>Cucumis melo</i>)	White gourd (<i>Benincasa hispida</i> Cogn.) <i>Cucumis</i> spp.; <i>Cucurbita</i> spp. <i>C. moschata</i> x <i>C. maima</i>
Cucumber (<i>Cucumis sativus</i> L.)	Pumpkin (<i>Cucurbita</i> spp.) <i>Cucurbita ficifolia</i>
Aubergine (<i>Solanum melongena</i> L.)	<i>Solanum integrifolium</i> ; <i>Solanum torvum</i> ; <i>Solanum melongena</i>
Tomato (<i>Lycopersicon esculentum</i>)	Tomato (<i>Lycopersicon esculentum</i>)



(a)



(b)



(c)

Figure 12-46

Grafting timeline for heirloom tomatoes. (a) Grafts in healing chamber. (b) Hardened-off grafted plant, with grafting clip falling off—ready for transplanting (52). Illustrations courtesy of C. Rivard and F. Louws.

the respiration process of the stored wood, but retard the passage of water vapor. Sometimes the natural moisture in the wood is sufficient, so slightly moist packing material is not needed in the sealed poly bags. In commercial field rose production, the scionwood (budwood) is harvested dormant, wrapped in slightly moist newspaper and sealed in poly bags, and maintained at -1.7 to -0.6°C (29 to 31°F) for up to 7 months.

The temperature at which the wood is stored is important. If it is to be kept only 2 or 3 weeks before grafting, the temperature of a home refrigerator—about 5°C (40°F)—is satisfactory. If stored for a period of 1 to 3 months, scionwood should be held at about 0°C (32°F) (6) to keep the buds dormant. However, buds of some species, such as the almond and sweet cherry, will start growth after about 3 months, even at such low temperatures. Do not store scionwood in a home freezer because the very low temperatures, about -18°C (0°F), can injure the buds.

Storage of scions should not be attempted if succulent, herbaceous plants are being grafted; such scions should be obtained at the time of grafting and used immediately. Certain broad-leaved evergreen species, such as camellias, olives, and citrus, can be grafted in the spring before much active growth starts, without previous collection and storage of the scionwood. Grafts are taken directly from the tree as needed, using the basal part of the shoots containing dormant, axillary buds. The leaves are removed at the time of collection.

Attempting to use scionwood in which the buds are starting active growth is almost certain to result in failure. In such cases, the buds quickly leaf out before the graft union has healed; consequently, the leaves withdraw water from the scions by transpiration, and cause the scions to die. In addition, the strong competing sink of a developing shoot can interfere with graft union formation.

In topworking pecans (4), good results are obtained by using precut scions; that is, scions cut in advance by skilled persons at a convenient time, that are then held in cold storage in polyethylene bags for up to 9 days before being inserted in the graft unions. Grafting success is reduced only slightly by the use of precut scions.

Handling of Rootstock for Bench Grafting. Seedling rootstock of maple (*Acer*) is established in liner pots for 1 year, brought into a greenhouse in the fall after leaf drop, and placed in bottom-heated benches at 13 to 16°C (55 to 60°F). Bench grafting of the container rootstock with a splice graft is done in January and February (Canada), when white roots appear along the perimeter of the rootballs (26).

In North Carolina, rootstock liners of woody ornamental plants are allowed to harden-off in minimum-temperature-controlled poly houses in the fall, and maintained just above freezing. When new roots emerge from the rootstock in late winter, plants are

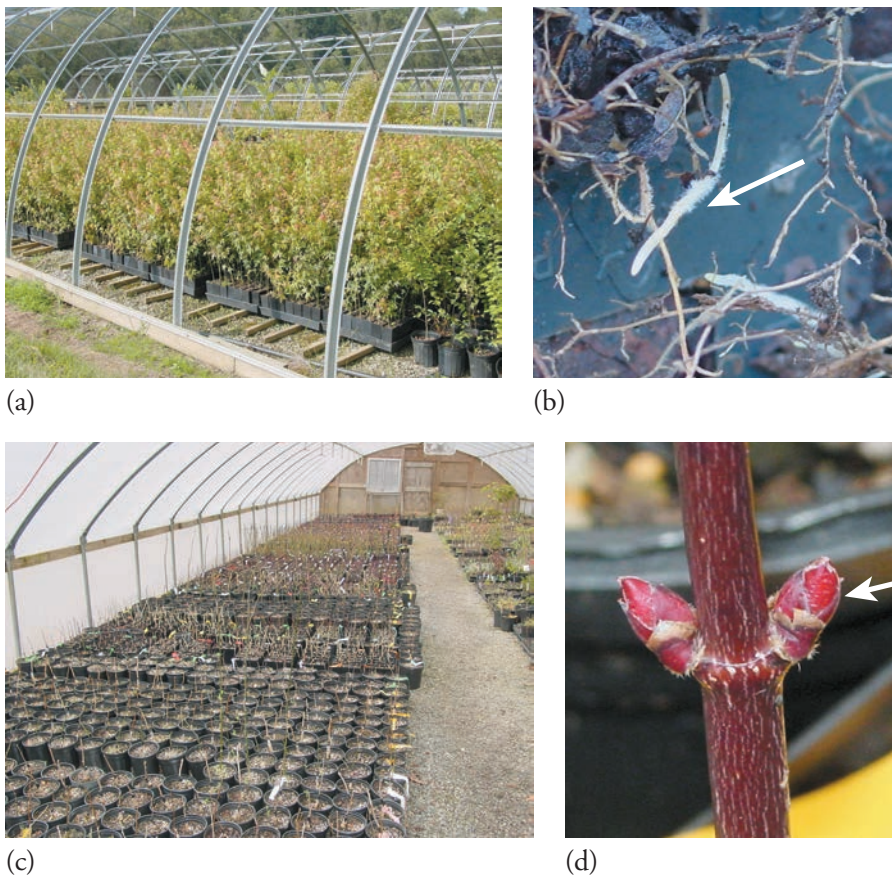


Figure 12-47

Proper rootstock preparation. (a) Hardening-off *Acer palmatum* rootstock liners in late September (North Carolina). (b) New roots emerging from rootstock in January prior to grafting. (c) Proper after-care of grafted, labeled plants in poly covered, temperature-controlled hoop house. (d) Buds swelling on grafted *A. palmatum* 'Fireglow' in mid to late March (56).

Courtesy B. L. Upchurch.

ready for grafting (Fig. 12-47) (56). In general, bench grafting is best when new, white root tips of 6 mm (1/4 in) occur or buds start to swell on the rootstock of potted liner plants.

The Craftsmanship of Grafting

Grafting is both an art and a skill. Successful grafting is a **repetitive task** that requires a high degree of accuracy and speed; to become skilled, it is essential for the grafter to eliminate all unnecessary movements. To increase grafting efficiency, it is important to organize the workplace so that scion material, knives, and grafting tape are all within easy reach (42). Grafting is generally more efficient with a **team approach**, in which each worker performs a certain task, in order to reduce inefficient motion of materials and repetitive picking up and putting down of different tools.

Manual Techniques: Speed, Accuracy, and Enhancing Success Rates Tips on improving grafting techniques and ergonomics include the following (42):

- Concentrate on accuracy first, and allow grafting speed to build up—aim at initially completing at least 200 bench grafts a day.
- Use a graft method that is less time-consuming (yet still successful!) and that can be done with lesser skill and preparation of the rootstock [e.g., bench grafting with a splice (whip) graft, compared to a whip-and-tongue or side-veneer graft (43)]; this works well with *Betula*, *Cornus*, *Fagus*, *Ginkgo*, *Quercus*, and *Acer* (26).
- Grafting is best with two people: in bench grafting with the whip-and-tongue, one person does the graft, and the other moves the potted liner rootstocks and waxes the graft union. In T-budding field roses, the budder prepares the rootstock and inserts the shield bud of the scion, while the “tier” follows and ties the budding rubber around the budded graft (see Fig. 13-13).
- The grafting knife should always be held with a relaxed grip to improve accuracy and reduce repetitive strain injuries (e.g., **carpal tunnel syndrome**); it is necessary to restrict and control your arm movements.
- There are two basic cuts in grafting: the **slice cut**, which is made using the arm and shoulder to pull the knife [e.g., in the making of a splice (**whip**) graft]; and the **cross cut**, in which the grafter’s arm and knife are rotated using the thumb

carpal tunnel syndrome

Nerve damage in the wrist caused by the stress of repetitive hand-arm movements.



as a pivot, with both hands joined to prevent the knife from cutting the grafter—a whip-and-tongue is created when the scion and rootstock are sliced and then cut across in **four** (economical) movements.

- Hang the grafting tape around your neck so that you know where it is and it stays free of contamination.
- In most cases, speed is more important than 100 percent accuracy; increase speed by developing a routine when grafting, and avoiding useless movements.
- Try to hold the grafting knife in your hand at all times (e.g., in your little finger).
- Make sure that everything is at a height that is easy to reach.

Record Keeping Maintaining good records is important for successful grafting.

- *Keep records on the grafters* to determine daily quantities grafted; some operations pay on a **piecework** or bonus system (see Chapter 10). Records kept by the supervisor can be

piecework A bonus system awarded to workers when they exceed daily graft production quotas.

constructively used to help grafters improve their technique and efficiency (9).

- *Keep records on the plant material* to determine the optimum windows of time to graft (43) and to assure having the best available material to graft. Records should be kept on the conditions of the grafting material, grafting problems encountered, and after-care of the grafts. Should a crop failure occur, records can generally help pinpoint the cause and help managers improve efficiency (9).
- *Importance of developing and sticking to a grafting time-line schedule.* A timeline schedule is critical for commercial success (Fig. 12–46).

AFTERCARE OF GRAFTED PLANTS

In Bench Grafting Systems

A common method of bench grafting is to wrap the union with budding rubbers, poly or plastic tape, plastic clips and silicone tubing, biodegradable cloth tape, or older materials such as raffia. Depending on the wrapping material, the entire union may be covered with grafting wax.

Root Grafting The root grafts may be placed under refrigeration at 7°C (45°F) for about 2 months. For general callusing purposes, temperatures from 7 to

21°C (45 to 70°F) are the most satisfactory. The callusing period for apples can be shortened to around 30 days if the grafts are stored at a temperature of about 21°C (70°F) and at a high humidity. To use this higher callusing temperature, the material should be collected in the fall and the grafts made before any cold weather has overcome the rest period of the scion buds. After the unions are well healed, the grafts must be stored at cool temperatures—2 to 4°C (35 to 40°F)—to overcome the “rest period” of the buds and to hold them dormant until planting (24). The root grafts are lined-out in early spring in the nursery row directly from the low-temperature storage conditions.

Hot-Pipe Callusing System With some plants, the graft union should be kept warm, 24 to 27°C (75 to 82°F), but the roots and the buds on the scion should be kept cool, about 5°C (41°F), to prevent premature growth before the graft union has callused and healed together. An ingenious system for regulating temperature was developed for whip-grafting hazelnut (*Corylus*), which are notoriously difficult to root graft (Fig. 12–48). This hot-pipe callusing system keeps the graft union warm by recirculating hot water in a PVC pipe onto which the graft is placed. The scion and roots protrude into areas of lower temperatures to keep the plant dormant until ready for transplanting. This hot-pipe callusing system, when used outdoors in late winter or early spring, has increased the root grafting “takes” of hazelnut and other difficult-to-graft species (31). Some aeration of the callusing grafts is required, so airtight containers should not



Figure 12–48

Hot-pipe callusing system for bench grafting difficult plants. The graft union is placed in a slot in a large plastic pipe. Inside the large pipe is a smaller pipe through which thermostatically controlled hot water circulates. Insulating material laid over this pipe retains the heat. The protected roots and scions protrude into areas of cooler temperatures, which retards their development.



be used. Virtually any graft used in bench grafting can be callused with the hot-pipe system, including apples, pears, peaches, and plums (32), and ornamentals such as *Acer*, *Cedrus*, *Corylus*, and *Fagus*. Not all species respond—the higher graft union temperature does not enhance graftage of spruce (*Picea*), for instance.

Closed Case Waxing may be omitted if the **bare-root grafts** are to be protected from drying by packing the grafts in boxes containing slightly moist peat. Some producers still dip the grafts in rose wax from the scion end to the taped union of the graft prior to boxing (51). Then the boxes are moved to a callusing room at 21°C (70°F) for about 12 days. Once the grafts have formed sufficient callus, the boxed grafts are held in cold storage at 2°C (35°F) until outplanted in the field (51). Another form of the closed case is the use of a **polytent** in a heated greenhouse for callusing the grafts of **potted rootstock liners** (Fig. 12–4). Provided light irradiance is controlled, glass mason jars can be used as a closed-case system for grafted plants in containers (Fig. 12–49).



(a)



(b)

Figure 12–49

(a and b) A closed case system of covering containerized grafted plants with glass Mason jars. (a) Uncovered plant. Condensate is visible inside the glass jars. (b) These grafted plants are maintained under shade to reduce the light irradiance and minimize heat buildup.

Open Case (Open Bench) Grafting is also done in a temperature-controlled greenhouse or unheated poly-house (depending on the season). Waxing can be omitted in the bench grafting of **potted rootstock liners** by plunging the container and burying the graft in slightly moist peat moss or bark in a temperature-controlled greenhouse. The medium is bottom heated and kept at 18 to 21°C (65 to 70°F) for 3 to 6 weeks for callusing; ideally, the air temperature should be cooler to discourage any initial top growth. Wrapping a graft with poly grafting tape is also sufficient without waxing. Optimum periods for grafting selected ornamental species in a greenhouse are listed in Table 12–5.

Outplanting of Bare-Root Grafts. As soon as the ground can be prepared in the spring, the grafts are lined-out in the nursery row 10 to 15 cm (4 to 6 in) apart. Grafts should be planted before growth of the buds or roots begins. If growth starts before the grafts can be planted, they should be moved to lower temperatures (–1 to 2°C, 30 to 35°F). The grafts are usually planted deep enough so that the graft union is just below the ground level, but if the roots are to arise only from the rootstock, the graft should be planted with the union well above the soil level [i.e., 7 to 15 cm (3 to 6 in)]. It is very important to prevent *scion rooting* where certain definite influences, such as dwarfing or disease resistance, are expected from the rootstock.

After one summer's growth, the grafts should be large enough to transplant to their permanent location. If not, the scion may be cut back to one or two buds, or headed-back somewhat to force out scaffold branches and allowed to grow a second year. With the older root system—a strong, vigorous top is obtained the second year.

Aftercare in Field and Nursery Grafting Systems

Aftercare of field- and nursery-grafted plants is described in “Production Processes of Graftage” starting on page 492. In the section “Types of Grafts” (page 466), see the descriptions for grafting and aftercare using such grafts as the whip-and-tongue, four-flap, and inlay bark graft. Chapter 11 describes heading-back (**lopping**) as well as the **crippling** techniques that are used in field and container nurseries to encourage the

crippling or lopping

Bending (restriction) or cutting halfway through the rootstock stem above the bud union to help force out the bud and maintain growth of the grafted plant. The rootstock tops are later cut off.



Table 12-5
"OPTIMUM WINDOWS" OF THE YEAR WHEN SELECTED ORNAMENTAL SPECIES CAN BE GRAFTED
IN THE GREENHOUSE IN OREGON, USA (43)

Crop	Month											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
<i>Abies</i>	X	X										X
<i>Acer palmatum</i>	X	X	X	X	X	X	X	X	X	X		
<i>Aesculus</i>	X	X	X				X	X	X			X
<i>Carpinus</i>	X	X	X	X						X	X	
<i>Cedrus</i>	X	X	X						X			
<i>Cercis</i>			X	X			X	X				
<i>Cornus</i>	X	X	X						X	X		
<i>Fagus</i>	X	X	X	X					X	X	X	
<i>Ginkgo</i>	X	X	X	X				X	X			
<i>Hamamelis</i>	X	X	X	X				X	X	X		
<i>Larix</i>	X	X										
<i>Liquidambar</i>		X	X					X	X			
<i>Liriodendron</i>		X	X						X	X		
<i>Picea</i>	X	X					X	X				X
<i>Pinus</i> spp.	X	X									X	X
<i>Wisteria</i>	X	X	X	X								

scions of grafted and budded plants to overcome the apical dominance of the rootstock and begin final production development.

Aftercare in Topworking Systems (Top-Grafting and Top-Budding) After the actual top-grafting (or top-budding) operation is finished, much important work needs to be done before the topworking is successfully completed. A good grafting job can be ruined by improper care of the grafted trees.

The trees should be carefully inspected 3 to 5 days after grafting, and the graft unions rewaxed if cracks or holes appear in the wax. However, using wax in top-grafting pecan trees is not feasible, given the high-temperature conditions of Texas, so inlay bark grafts are covered with aluminum foil and polybags to control desiccation and heat stress during the grafting process (Figs. 12-13 and 12-24). In Israel the grafts of topworked peaches have aluminum covers to reduce heat buildup (Fig. 12-24).

FIELD, BENCH, AND MISCELLANEOUS GRAFTING SYSTEMS

Some of the different grafting systems have been described in the sections on **types of grafting** and the **production processes of graftage**. Grafting systems are categorized as field, bench, and miscellaneous grafting systems (Table 12-6).

Field Grafting Systems

Crown Grafting The **crown graft** originally referred to scions grafted onto larger rootstock. The large rootstock stem was grafted with a number of scions, which sometimes were in a crown-like circle (19). Today, the term includes grafting onto an established rootstock with single or multiple scions, using the whip-and-tongue, cleft, wedge, side-veneer, inlay bark graft, and others. The choice of the graft depends on the species and size of the rootstock. In California, seedling walnut trees are planted in the nursery and then grafted at the crown—close to the junction of the root and shoot—of the rootstock.

crown grafting

Grafting that is done at the **crown** of the rootstock, which is the junction of the root and shoot system. In earlier times it referred to grafting several scions in a crown-like circle onto an established larger rootstock.

Crown grafting of deciduous plants is done from late winter to late spring. In each species, grafting should take place shortly before new growth starts. The scions should be prepared from mature, dormant wood of the previous season's growth.

If the graft is above the soil level, the union must be well tied (or nailed) and sealed to firmly hold the graft and prevent desiccation. However, when the operation is performed just below, at, or just above the soil



Table 12-6
FIELD, BENCH, AND MISCELLANEOUS GRAFTING SYSTEMS

Field Grafting Systems

- Crown graftage
- Topworking
- Frame working
- Repair graftage—see page 487
- Double-working (by grafting and budding)—sometimes bench grafted

Bench Grafting Systems—see page 502

- Root graftage
- Nurse-root graftage
- Grafting of plants in liner pots under protected culture
- Herbaceous grafting—including grafting of vegetable crops
- Approach graftage—sometimes field grafted

Miscellaneous Grafting Systems

- Cutting grafts—simultaneous rooting and grafting (stenting) of roses, citrus, etc.
- Micrografting

level, it is possible to cover the graft union, or even the entire scion, with soil and thus eliminate the necessity for waxing or ceiling. In all cases, the union should be tied securely with tape to hold the grafted parts together until the graft takes.

Topworking **Topworking** is used primarily to change the cultivar of an established plant—tree, shrub, or vine—by grafting (see Fig. 12-24). Topworking can be done with any of the apical or side graftage grafts described earlier in this chapter, depending on the plant species. This procedure may be preferred to removal and replacement of the entire plant, since a return to flowering and fruiting is faster with topworking an established plant than with transplanting a new nursery plant—particularly if the topworked plant is young, healthy, and well cared for. Plants that are old, diseased, or of a short-lived species are not satisfactory candidates for topworking.

Preparation for Topworking. Top-grafting is usually done in the spring, shortly before new growth starts. The exact time depends on the method to be used. The cleft, side, whip, and wedge grafts can be done before the bark is slipping, but the bark graft must be done when the bark is slipping, preferably just as the buds of the stock tree are starting to grow.

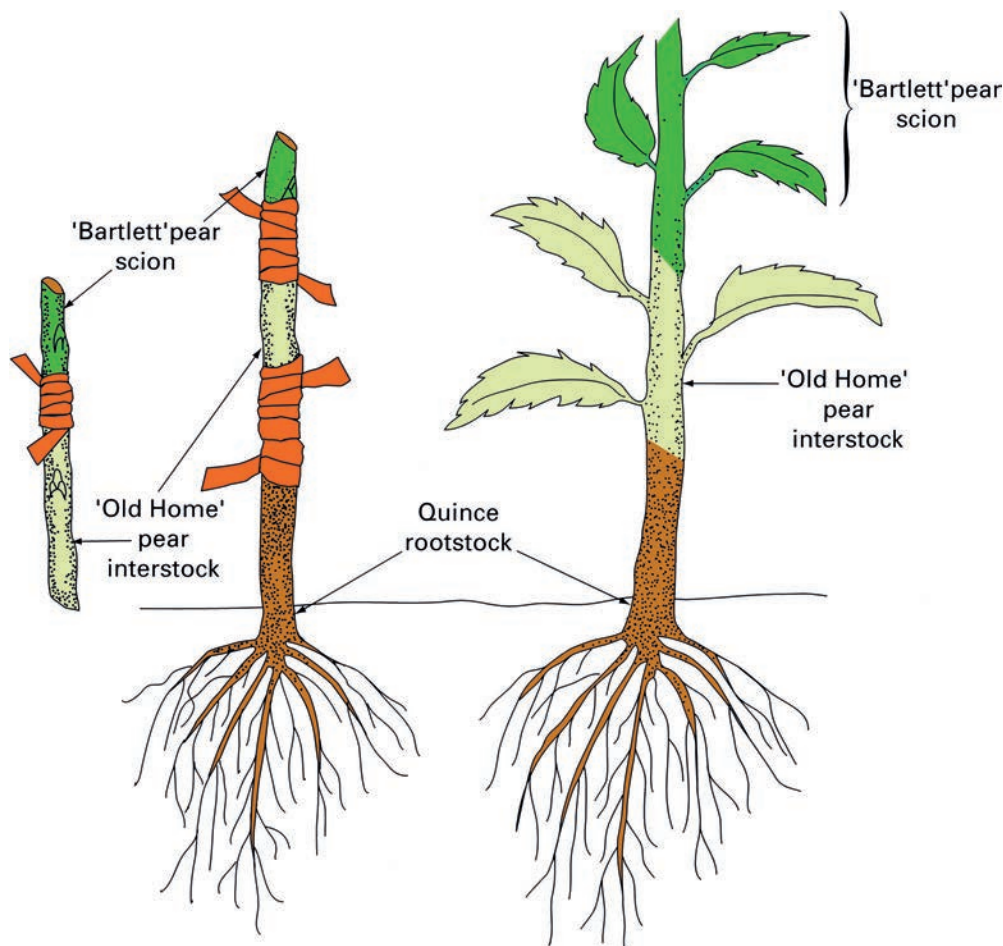
It is usually advisable to obtain an ample amount of good-quality scionwood prior to grafting and store it

under the proper conditions, although for broad-leaved evergreens, such as avocado or citrus, scionwood can be collected at the time of the grafting operation. See the earlier section on the selection and handling of scionwood (page 496).

In preparing for topworking, one must decide for each individual rootstock tree how many scaffold branches, if any, should be used (usually 3 to 5). However, no scaffold branches are retained when topworking pecans in Texas with the inlay bark method.

Double-Working (Grafting or Budding) A double-worked plant has three genetically distinct parts: the rootstock, the interstock, and the scion (Fig. 12-50). Such a plant has two unions, one between the rootstock and interstock and one between the interstock and the scion. The interstock may be less than 25 mm (1 in) in length or extensive enough to include the trunk and secondary scaffold branches of a tree.

Double-working is used for various purposes (see Chapter 11 and Chapter 13). Examples of double-working are (a) the propagation of ‘Bartlett’ pears on quince as a dwarfing rootstock by using a compatible interstock such as ‘Old Home’ or ‘Hardy’ pear (Fig. 12-50, page 506), and (b) the propagation of dwarfed apple trees consisting of the scion cultivar grafted onto a dwarfing ‘M 9’ or ‘M 27’ interstock that is grafted onto a more vigorous rootstock such as ‘MM 106,’ ‘M 111,’ or apple seedlings (Fig. 11-11) (10). Another form of double working is using a bridge-graft with a dwarfing rootstock (as the interstock) on older, mature apple rootstock in an established orchard, as previously described (53).

**Figure 12-50**

There are three genetically distinct parts and two graft unions in a doubleworked plant. The 'Bartlett' pear scion is grafted on an 'Old Home' pear interstock—then grafted to quince rootstock.

Several methods are used for developing doubleworked nursery trees. The grafting in these techniques can be done with the whip graft:

- Rootstock “liners”—seedlings, clonal rooted cuttings, or rooted layers—are set out in the nursery row in early spring. These are then fall-budded with the interstock buds, growth from which, a year later, is fall-budded with the scion cultivar buds. Generally, 3 years are required to produce a nursery tree by this method.
- The interstock piece is bench grafted onto the rooted rootstock—either a seedling or a clonal stock—in late winter. After callusing, the grafts are lined-out in the nursery row in the spring, and fall-budded to the scion cultivar. By this method, the nursery tree is propagated in 2 years.
- A variation of the previous method is to prepare, by bench grafting, two graft unions—the scion grafted to the interstock and the interstock grafted to the rooted rootstock. After callusing, the completed graft, with two unions, is lined-out in the nursery row. Depending on growth rate, a nursery tree can be obtained in 1 or 2 years.
- Double-shield budding (T-budding) is used for double-working in one operation by budding (Fig. 13–21). A nursery tree is produced in 1 year or, if growth is slow, 2 years after budding.
- The interstock shoots still on the plant can be T-budded in late summer with the scion buds inserted about 15 cm (6 in) apart. During late winter, the budded interstock shoots are removed with the budded scion at the terminal end of each piece and bench grafted with a whip graft onto seedling rootstocks. After callusing, the completed graft—now consisting of rootstock interstock and a budded scion—is ready for planting in the nursery row (16).

Bench Grafting Systems

The term **bench grafting (bench working)** traditionally refers to any graft procedure performed on a rootstock and scion that are not initially planted, including root graftage, nurse-root graftage, or any graftage performed on bare-root rootstock. Bench grafting also applies to potted liner rootstock that is grafted on a bench or table, as is commonly done with selected

**Figure 12-51**

(a and b) Bench grafting of vegetables in Canada and Japan. (c) Machine grafted cucumber cuttings. (d) Growing grafted seedlings indoors under artificial lights (29). Courtesy C. Kubota.

woody ornamental species (43) or selected vegetable crops (Fig. 12-51) (29). Certain approach grafts are bench grafted, while others, such as the spliced approach graft of mangos in India, are field grafted, with the potted rootstock grafted to the established scion in the field.

Herbaceous types of plants are grafted for various purposes, such as studying virus transmission, stock-scion physiology, and grafting compatibility, as well as for the commercial greenhouse and field production of selected vegetable crops, particularly in Japan, Korea, and Europe (Fig. 12-51). The rootstock is grafted shortly after seed germination, while the plants are quite small. Such material is generally very soft, succulent, and susceptible to injury. The one cotyledon graft (OCG) or Japanese tube graft, is described in detail (see Figs. 12-6, 12-7, and 12-46) (21). Automated procedures of vegetable grafting using robotics and plastic grafting clips were described earlier (Figs. 12-43, 12-44, and 12-45).

Miscellaneous Grafting Systems

Cutting-Grafts In the cutting-graft, a leafy scion is grafted onto a leafy, unrooted stem piece (which is to become the rootstock), and the combination is placed in a rooting medium under intermittent mist for simultaneous grafting and rooting of the rootstock. Leaves must be retained on the rootstock piece in order for it to root. This procedure was utilized many years ago in studying stock-scion physiology in citrus (20), and has been used in commercial propagation of various types

of citrus on clonal dwarfing rootstocks (13). It is also of value in propagating certain difficult-to-root conifers (55), rhododendrons (15, 41), and macadamias (1), as well as a number of apple, plum, and pear cultivars (44). It is used in the Netherlands and Israel in propagating greenhouse roses, where it is called **stenting** (Figs. 12-52 and 12-53) (58, 59).

stenting A Dutch term for simultaneously grafting and rooting the rootstock.

For citrus, a simple splice graft is used. The slope of the cut is at a 30-degree angle 1.3 to 2 cm (1/2 to 3/4 in) long; the union is tied with a rubber band. The base of the rootstock is dipped into an auxin, such as IBA, and then the grafts are placed under mist, or in a closed case, in flats of the rooting medium over bottom heat. After healing of the union and rooting of the stock, the grafts are allowed to harden by discontinuing the mist and bottom heat for about 2 weeks. Then the grafts are ready to be planted in 3.8-liter (1-gal) containers.

Micrografting Grafting of tiny plant parts can be done aseptically using tissue culture techniques described in Chapters 17 and 18, in which the small grafts are grown in closed containers until they are large enough to be transferred to open conditions. Micrografting has been used mostly with citrus, apple, and some *Prunus* species to develop virus-free plants, where a virus-free shoot tip can be obtained but cannot be rooted. The shoot tip is grafted aseptically onto a virus-free seedling, thus providing a complete virus-free plant from which other



(a)



(b)



(c)



(d)

Figure 12-52

Simultaneously grafting and rooting roses for cut flower production in Israel. (a and b) Rooting in Rockwool rooting blocks. (b and c) Grafted rose with plastic graft clip for simultaneous rooting and successful callus bridge formation. (d) Rooted, stented rose.



(a)



(b)



(c)



(d)

Figure 12-53

Roses in the Netherlands being propagated by simultaneous rooting and grafting. (a) *Left*: Shoot cut apart to be used for rootstocks. Only internodes are used. *Right*: Sections cut for scions. One leaf is used per scion. (b) Saddle graft made with an Omega grafting machine. (c) Graft wrapped with tape for healing. (d) Completed graft with union healed and stock well rooted, ready for planting. In the Netherlands this process is called "stenting," a contraction of the Dutch words *stekken* ("to strike a cutting") and *enten* ("to graft"). Courtesy P. A. Van de Pol (58, 59).



“clean” plants can then be propagated (8, 25, 27, 46). Tests conducted some years after the shoot-tip grafts were made and the resultant trees were fruiting showed that the fruits were normal for the cultivar, disease-free, and with no variations appearing (45). The procedures for micrografting are described in Chapter 17.

Micrografting can also be done without tissue culture techniques. The non-aseptic propagation of

very small nursery trees by grafting tiny seedlings with match-like scions, then growing the minute grafts long enough to have a viable plant, is a promising procedure (60). This is useful particularly in the tropics, where nursery plants sometimes must be shipped long distances, often by air, into inaccessible regions. Quantities of such tiny plants can be transported much more readily than full-sized nursery trees.

DISCUSSION ITEMS

1. What are five important requirements necessary for successfully producing a grafted plant?
2. What are the three major types (classifications) of grafts, and what criteria are used to categorize a specific graft into one of these three types?
3. What are the three types of nurse-root grafts? Why use an expensive process such as nurse-root grafting?
4. How does approach graftage differ from repair graftage? Give examples of grafts used.
5. Why are grafting waxes not used as much today as in the past? What kinds of substitutes are being used in their place?
6. Why is there increased interest in grafting automation/robotics?
7. What are some important considerations in the collection, handling, and storage of scionwood for grafting?
8. The craftsmanship of grafting includes both art and skill. How can an individual improve techniques and ergonomics to become a better grafter?
9. What are some good cultural techniques to enhance aftercare in topworking (topgrafting) an orchard with a new cultivar?
10. How do field grafting systems differ from bench grafting systems? Include examples of the various types of grafts in your answer.
11. Why the interest in herbaceous grafting, and with what crops is this technique of commercial importance? Why does this type of grafting lend itself to automation/robotics?
12. Contrast cutting grafts with micrografting, and give examples of their commercial use.

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