Propagation of Plants by Grafting and Budding

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Contents

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By G.N.M. Kumar

Introduction

Most plants multiply from their seeds. Certain plants are preferentially multiplied from their parts such as stem, roots, or leaves. Multiplication of plants using parts other than seeds is known as vegetative (asexual) propagation and the resultant plants are referred to as clones. For various reasons (see below), some plants are multiplied by combining vegetative plant parts (stem or vegetative buds) from two separate plants into one.

Grafting and budding are techniques used to combine one plant part with another to encourage growth as a unified plant. Grafting is accomplished by inserting a piece of stem containing 3 to 4 vegetative buds onto the stem of the plant that will serve as the root system for the unified plant. In nature, two closely related plants growing in proximity may establish graft union on their own, as in the case of the silver maples shown in Fig. 1. For budding or bud grafting, a single vegetative bud on a stem is excised (see Fig. 2) and attached to the stem of the rootstock. The plant that develops is known as a budded plant. Budding is preferred to grafting when plant material is in limited supply.

Fig. 1. Establishment of a graft union between two silver maple trees growing in close proximity. Graft union between the two trees occurred naturally. (Photo courtesy of Sarah Moore, Pullman, WA)

Reasons for propagating plants by grafting or budding

The major objective of grafting or budding is to multiply plants identical (true-to-type) to the parent plant. Although propagation of plants via methods other than grafting and budding are much simpler, grafting and budding are used as the principal methods of propagation in certain plants such as fruit trees.

Fig. 2. The individual vegetative buds on the stem piece can be excised as shown here and used as scion. This method of plant propagation is termed as "bud grafting" or simply "budding."

Grafting and budding are used as methods of choice to 1) propagate plants when relatively simpler methods such as stem cuttings,[1] layering,[2] or seeds are ineffective, climatic or soil conditions are unfavorable, or major modifications to plant architecture are needed; 2) change plant cultivars; and 3) repair damaged plants.

For example, cuttings taken from mature fruit trees fail to root well since the ability to develop roots declines with advancing plant age. In addition, most fruit trees are cross-pollinated and therefore progenies seldom maintain the desirable characteristics of the parent plant.

Grafting can be used to make trees less vigorous and accommodate more plants per unit of land. Such high-density orchards are more productive. Plants grafted on dwarfing rootstocks have a tendency to fruit early and be easily accessible for orchard operations such as pest management and harvesting.

If the fruit cultivar grown in your orchard has lost consumer acceptability, a more desirable cultivar can

[1] Induce root formation on pieces of stem, roots, or leaves.

[2] Induce root formation on stems attached to the mother plant.

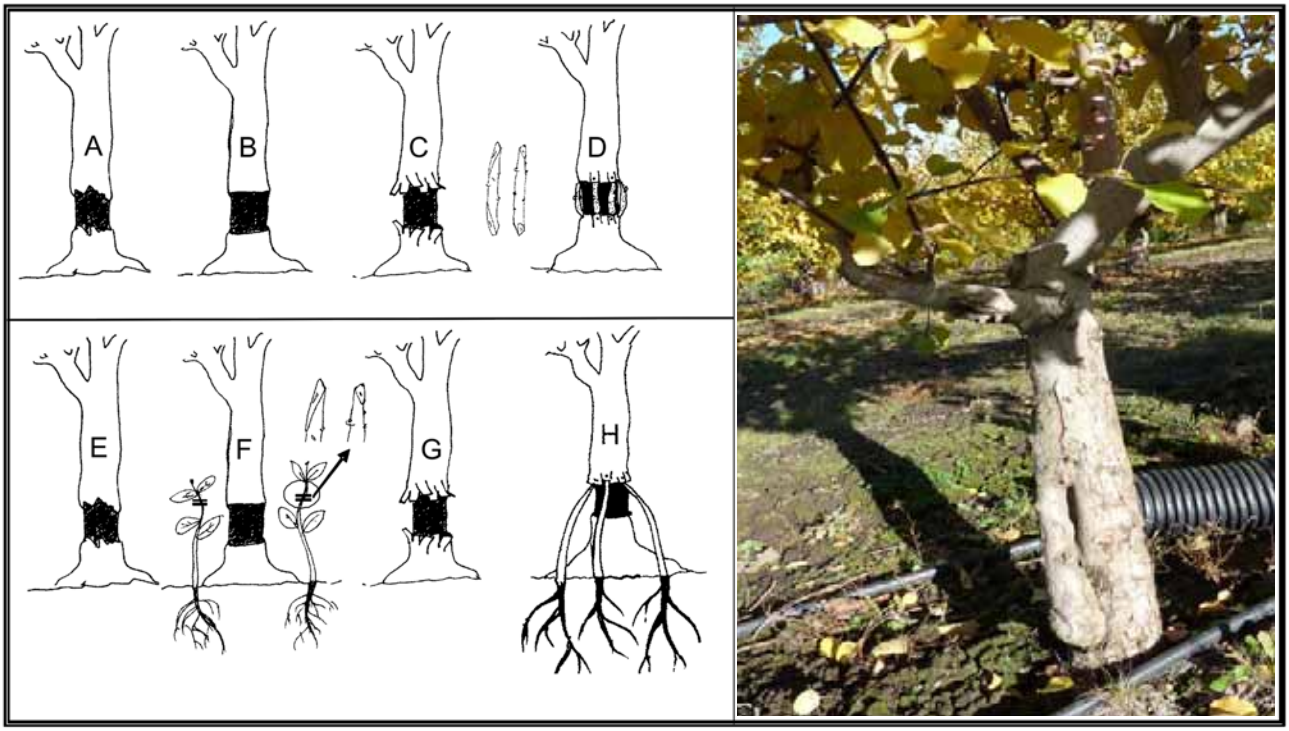

Fig. 3. Bridge grafting (A–D) and inarching (E–H) as methods to repair damaged tree trunks and restore phloem conductivity to the root zone. The photograph to the right shows a successfully bridge-grafted apple tree.

be grafted onto the existing mature tree by topworking. This procedure is more economical than new orchard establishment.

Grafting can also be used to repair damaged plant parts. For example, trees girdled by rodents just above the soil level often die due to lack of carbohydrate transport to the roots. Such trees can be saved by reestablishing the conduction of nutrients between root and shoot via repair grafting (see Fig. 3). In addition, grafting can produce interesting plant combinations, as shown in Fig. 4.

Grafting and budding vocabulary

Before discussing these methods further, some of the key terms involved need to be clarified.

- The **scion** is the part of the stem that develops into a shoot system following successful grafting.
- The **stock** or **rootstock** is the part that develops into a root system following successful grafting. A rootstock may be grown from seed or from rooted cuttings.
- An **interstock** is sometimes grafted in between a stock and scion to impart certain important characteristics to the unified plant. Interstocks are useful for dwarfing, to overcome stock-scion incompatibility, impart winter hardiness, and reduce disease problems. (The interstock may be only a thin section of wood, a short section of trunk in a fruit tree, or the trunk and lower portions of scaffold branches.) This is often referred to as "double working."
- **Topworking** applies to the process of changing the top of a plant from one cultivar to another by grafting or budding. This procedure may sometimes involve a series of multiple grafts.
- The **cambium** is a layer of dividing cells in a stem that is responsible for increasing the stem diameter. Plants lacking cambium (example: monocots such as corn) cannot be grafted. The cambium of a stock and scion must be in close contact to form a union. Cambial activity during spring facilitates easy separation of bark from the wood.
- **Callus** is a mass of cells produced from the cambium. The newly formed mass of cells grows over the wound and unites the plant parts. Thus, callus plays a crucial role in uniting the stock and scion.
- **Bench grafting** is uniting container-grown or bare-root rootstocks with scion indoors, often on a bench.
- **Sap** is the fluid transported via conductive tissues such as **xylem** and **phloem**. While **xylem**

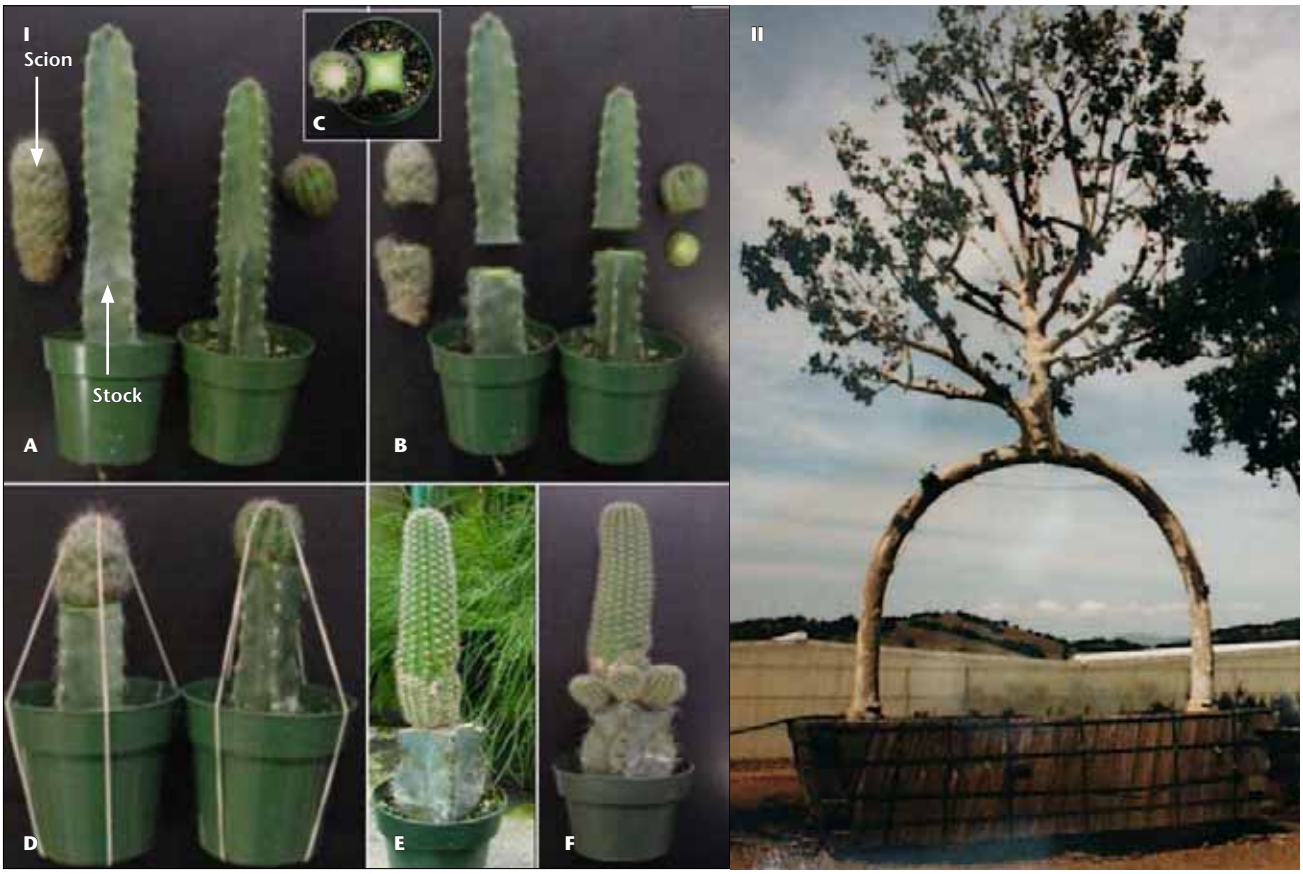

Fig. 4. Grafting can be employed in developing interesting plant combinations such as the following. I) Grafting cactus: A) The potted cactus will serve as rootstock for the intended scion; B) The rootstock is given a smooth cut 3–4 inches above the ground while the scion is cut 3–4 inches from the tip; C) Top view of the smooth cuts given on the stock and scion; D) The scion is placed on the stock in such a way that their cut surfaces are in contact with each other. For successful graft union, the vascular cambium of stock and scion should be in close contact. It may be necessary to place the scion on the stock a little off-centered when the diameter of stock and scion are not equal. This helps in the establishment of cambial contact on at least on one side. The stock and scion are held in place using rubber bands; E, F). Successfully grafted cactus. (Photographs courtesy of T. Ombrello, Biology Department, Union County College, Cranford, NJ) II) Approach grafting of plants grown in two different containers to develop an arch. (Gilory Gardens Inc., CA; courtesy of Andy Kaufman, University of Hawaii, Manoa)

transports water from roots to the aerial parts of the plant, **phloem** conducts sugars, nutrients and hormones from the leaves to the roots and storage organs (fruits).

Factors affecting the success of grafting or budding

Besides good grafting skills, success in grafting or budding depends on a number of factors related to the plant and surrounding environmental conditions.

- *Time of year:* In general, spring to late summer is desirable for grafting or budding outdoors. During spring, the environmental conditions are conducive for active growth of plants. Spring is also associated with restoration of cambial activity and flow of sap which result in easy removal of bark (slippery bark) to facilitate grafting and/or budding operations (Fig. 5). Budding done in early summer in areas with long growing seasons (i.e., parts of California) is called "June" budding. Budding done in August or early September is called "fall" budding. However, grafting and budding can also be done during winter on certain deciduous plants. Bare-root rootstocks are grafted in winter and maintained indoors. When planted the following spring, the grafted or budded plant resumes growth. This technique is commonly known as "bench grafting."
- *Compatibility of stock and scion:* For grafted plants to unite and grow successfully, the combined plant parts (stock and scion) should be compatible with each other. Closely related plants have a good chance of forming a union, while those remotely related have little or no chance.

Fig. 5. "Slippery bark" facilitates grafting and budding operations by allowing easy lifting of bark to insert the bud (scion).

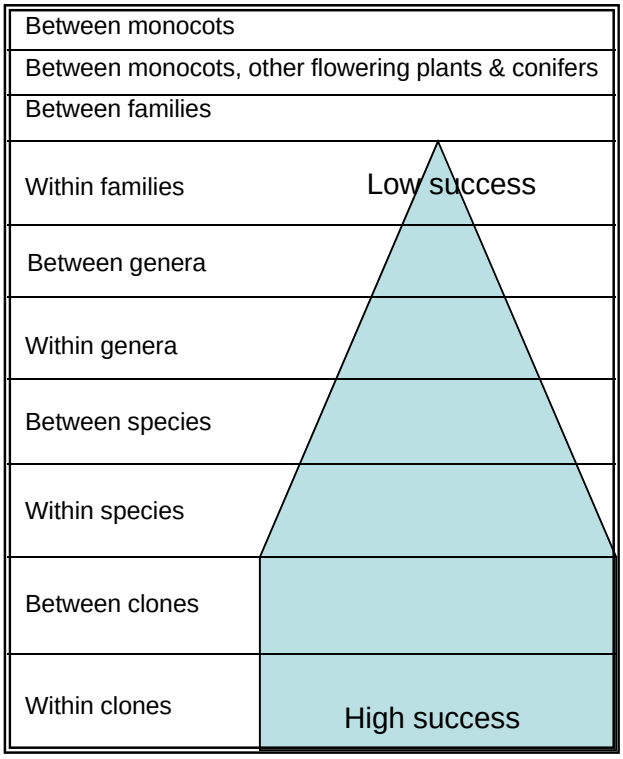

Fig. 6. The effect of a botanical relationship on the success of union between stock and scion. Plants belonging to monocots (e.g., the grass family) lack cambium and cannot be grafted. Similarly, monocots cannot be grafted on to dicotyledonous plants. Therefore, they are placed outside the compatibility pyramid. Closely related plants have a good chance, while those remotely related have little or no chance of forming graft union. The highest success in grafting or budding can be achieved by grafting plants within or between clones.

This concept is explained in the compatibility pyramid (Fig. 6). Plants in the grass family and other monocotyledonous plants cannot be grafted or budded, so they are outside the compatibility pyramid. Conifers and other flowering plants, as well as many herbaceous and woody plants, can be grafted. The highest success in grafting or budding is achieved by grafting plants within or between clones.

The term "graft incompatibility" refers to unsatisfactory graft union that may or may not lead to a total failure. For example, incompatibility caused by the overgrowth of a rootstock (Fig. 7) may not lead to death of the unified plant.

Of particular importance is the cambial ring located between the vascular tissues of the stock and scion, namely, the xylem and phloem. The xylem is involved in the transport of water from root to the aerial parts, while the phloem conducts sugars, nutrients, and hormones from the leaves to the roots and storage organs. The cambium is the layer of dividing cells in the stem that is responsible for increasing in stem diameter. Figure 8B is a demonstration of a failure to match the cambial layer of stock and scion.

- *Temperature:* Grafting is usually completed during the dormant season when temperatures are cool. Graft union formation is slow at 40°F (4°C) or lower. If temperatures become too warm soon after grafting, shoot buds may grow and produce a leaf surface that depletes moisture reserves in the scion before a graft union is formed. For this reason, temperatures should not exceed 60°F (15°C) for 2–3 weeks following grafting unless scion buds are still in their rest period. The rest period is a physiological condition preventing growth of deciduous woody plants, completed by exposure to cool temperatures (42°F [5°C] or less) that stimulate further growth. Union formation following summer budding is favored by temperatures around 70°F (21°C) when callus formation is rapid. Temperatures above 90°F (32°C) slow or stop callus formation.
- *Age of plant parts:* Budsticks should be 1 year or less; scions 1 to 2 years old, and rootstocks 2 years or less.
- *Scion orientation (polarity):* For a graft union to be successful, the stock and scion should be oriented the way they normally grow (e.g., scions grafted or budded upside down seldom form a successful graft union).
- *Care of grafted plants:* The surfaces of the stock and scion at the union must be protected from drying. Cover the exposed surface after scion and stock are fitted together with grafting wax or other

Fig. 7. An apple graft showing signs of incompatibility. Note the overgrowth of rootstock in relation to the scion.

protective materials (see Fig. 9C) such as moist peat moss. Grafts may also require re-waxing, tying for support, or light pruning to direct growth after shoots emerge.

- *Soil moisture:* For maximum cambial activity, the soil moisture supply must be ample. Adequate soil moisture is particularly important during and shortly after summer budding.
- *Contact of stock and scion:* Graft and bud unions are promoted by a good, snug fit between the new stock and scion. In some cases, such as cleft grafting, the fit is natural (see Fig. 10C, F). In other methods of grafting, tying materials promote proper contact between the stock and scion. Clean and smooth cuts on the stock and scion are required to promote maximum contact.

Tools and materials required for grafting and budding

In addition to the plant material, the following tools and materials (see Figs. 11 and 12) are needed to complete grafting or budding operations.

- *Knives:* Although one type of knife can be used

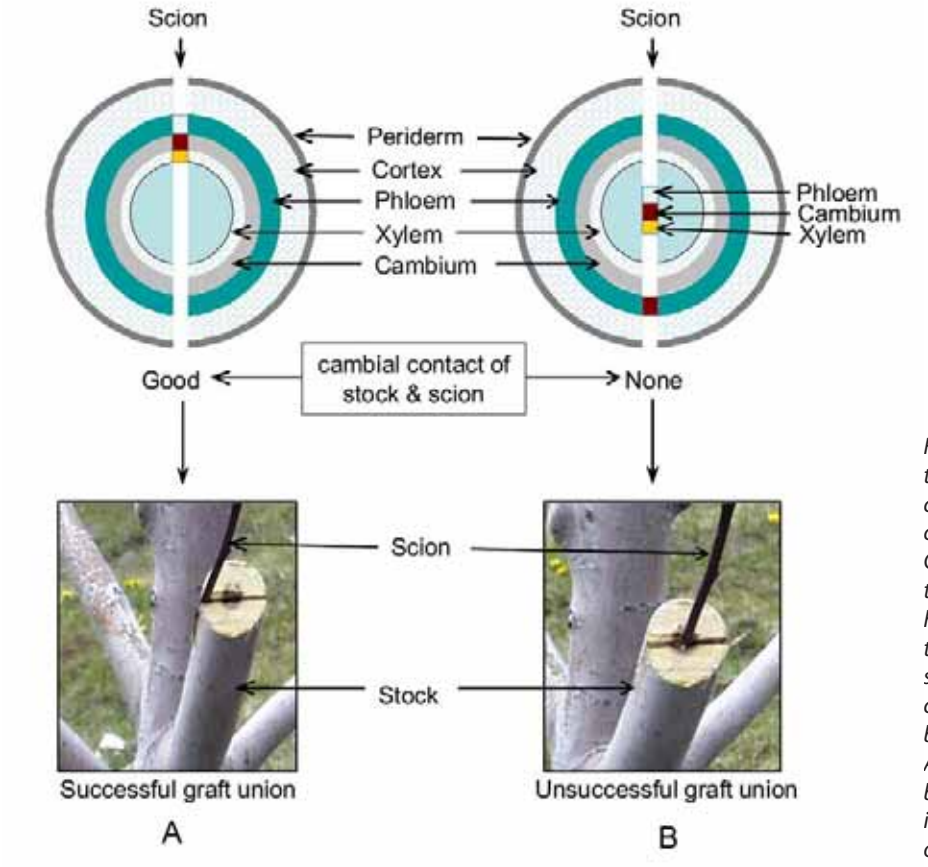

Fig. 8. Schematic presentation of the tissues involved in grafting. The cambial ring is located in between the conductive tissues (xylem and phloem). Conductive tissues are involved in the transport of water (xylem) and carbohydrates (phloem). During graft union, the cambial cells divide and facilitate successful graft union formation. The cambium of the stock and scion must be in close contact to form a union. A proper alignment of cambial layer between the stock and scion is shown in A. Failure to match the cambial layer of stock and scion (B) results in failure of the graft union.

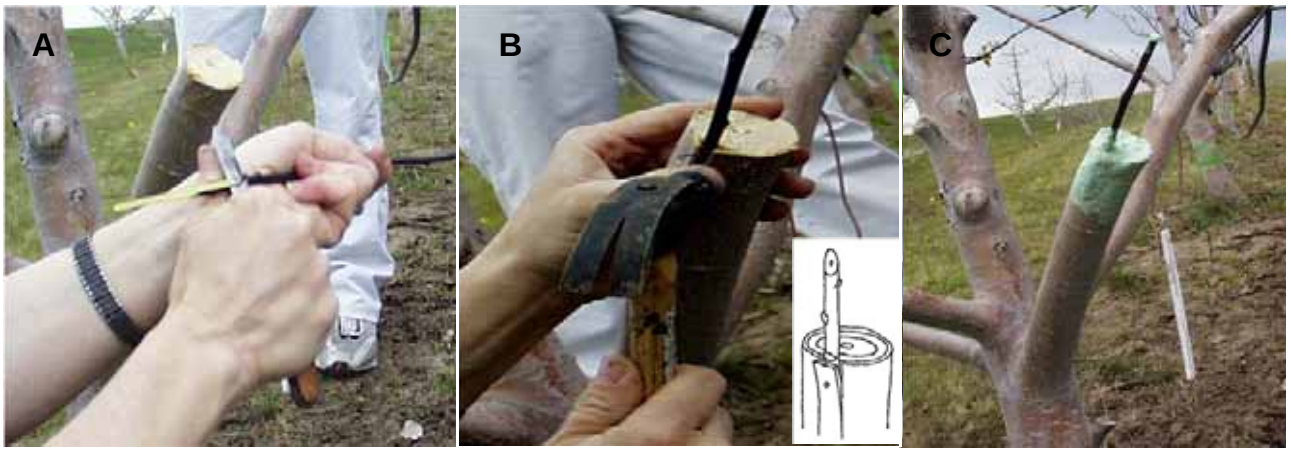

Fig. 9. Cultivars of well-established trees can be changed by topworking with new and improved cultivars using bark grafting. A) The branch of an established tree is cut using a saw and the scion of a new cultivar is prepared by giving cuts to expose the cambial layer. B) The bark on the stock is carefully lifted following a vertical cut (1.5–2 inches long) and the prepared scion is inserted between the bark and the wood. The scion is held in place by driving 1–2 nails through the bark and into the wood. Inset: schematic showing the proper method of inserting the scion. C) The grafted area is covered with wax and a graft sealing compound (see Fig. 11). Failure to protect the wounded tissue results in desiccation and/or microbial invasion. (Line drawings reproduced from PNW496, 1996)

Fig. 10. Steps in cleft grafting (top working) well-established trees (A–D). Plants with small diameters can also be grafted by this method (E–H). Inset A: Using a cleft grafting tool to open the cleft; Inset C: Two scions can be inserted into the cleft. (Line drawings reproduced from PNW496, 1996)

Fig. 11. Tools and materials required for performing grafting and budding operations successfully.

for budding and grafting, special knives are best suited for each operation. Such knives differ primarily in blade shape. Grafting knives have straight blades, whereas budding knife blades curve upward at the end. A cutting blade with high quality steel that will take and hold a good edge is desirable. Some budding knives also have a bark opener at one end. This blunt tool is useful in lifting the bark on the stock prior to insertion of the bud.

- *Other tools:* For cleft grafting, a wooden mallet and clefting tool are useful (Figs. 10 and 11). The clefting tool is used to split the stock and hold it open for insertion of the scions. Pruning shears and saws are also handy tools.

- *Sharpening stone:* A good quality, fine-grained stone is important for developing a sharp edge on your knife, which is essential for making smooth, straight grafting and budding cuts needed for successful graft union.

- *Protective and tying materials*. Waxing is most commonly practiced to protect grafts from drying. Some waxes must be heated and applied with a brush, while others are soft and pliable enough to be applied cold by hand. Cold liquid wax emulsions and latex-based materials to be brushed on are also available.

  Electrician's tape, adhesive cloth, or masking-type paper tape are also frequently used to protect grafts; if applied under tension, tapes will additionally hold the joined parts snugly and promote union formation. If tapes are properly applied, waxes or similar coverings are not needed. However, tapes are not readily adapted for application to all types of grafts. Waxed string or rubber budding strips are sometimes used to tie grafts; they must be covered with a layer of wax to adequately protect the graft. Strips of thin rubber about 3/16 inch wide or plastic strips are commonly used to tie buds securely to the stock; string and tape are other options.

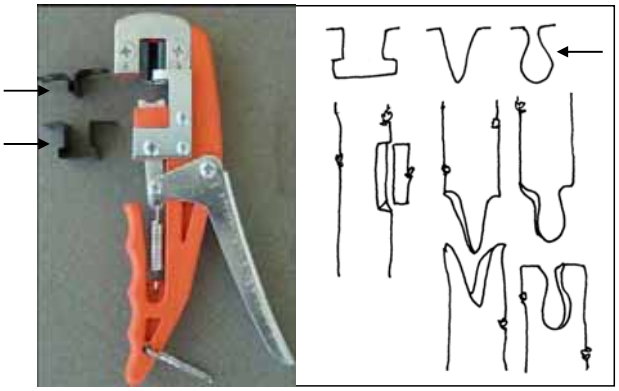

Fig. 12. Grafting tool for making perfect cuts on a stock and scion. This tool can be fitted with any of the three types of blades (indicated by arrows) depending upon the type of grafting. The precision cuts allow close cambial contact and ensure a high rate of success in grafting.

Collection and handling of scion material

If freezing temperatures are likely to damage plant tissues, collect scion wood for grafting in the fall after normal leaf drop but before severe winter temperatures. Otherwise, wait to collect until late winter. Store the wood in a plastic bag. Enclose a moist cloth, but leave no free water in the bag. Store the wood in a refrigerator between 35°F (1.7°C) and 40°F (4°C). Make sure that fruits or plant materials capable of generating ethylene gas (plant hormone that induces ripening/senescence) are stored in a different cooler than the scions or rootstocks. If refrigeration is unavailable, store the wood outdoors in moist sand in a well-drained, protected location where the soil will not freeze.

For spring budding, use the same scion wood as you would for grafting. For budding during the growing season, choose new shoots of the current season's

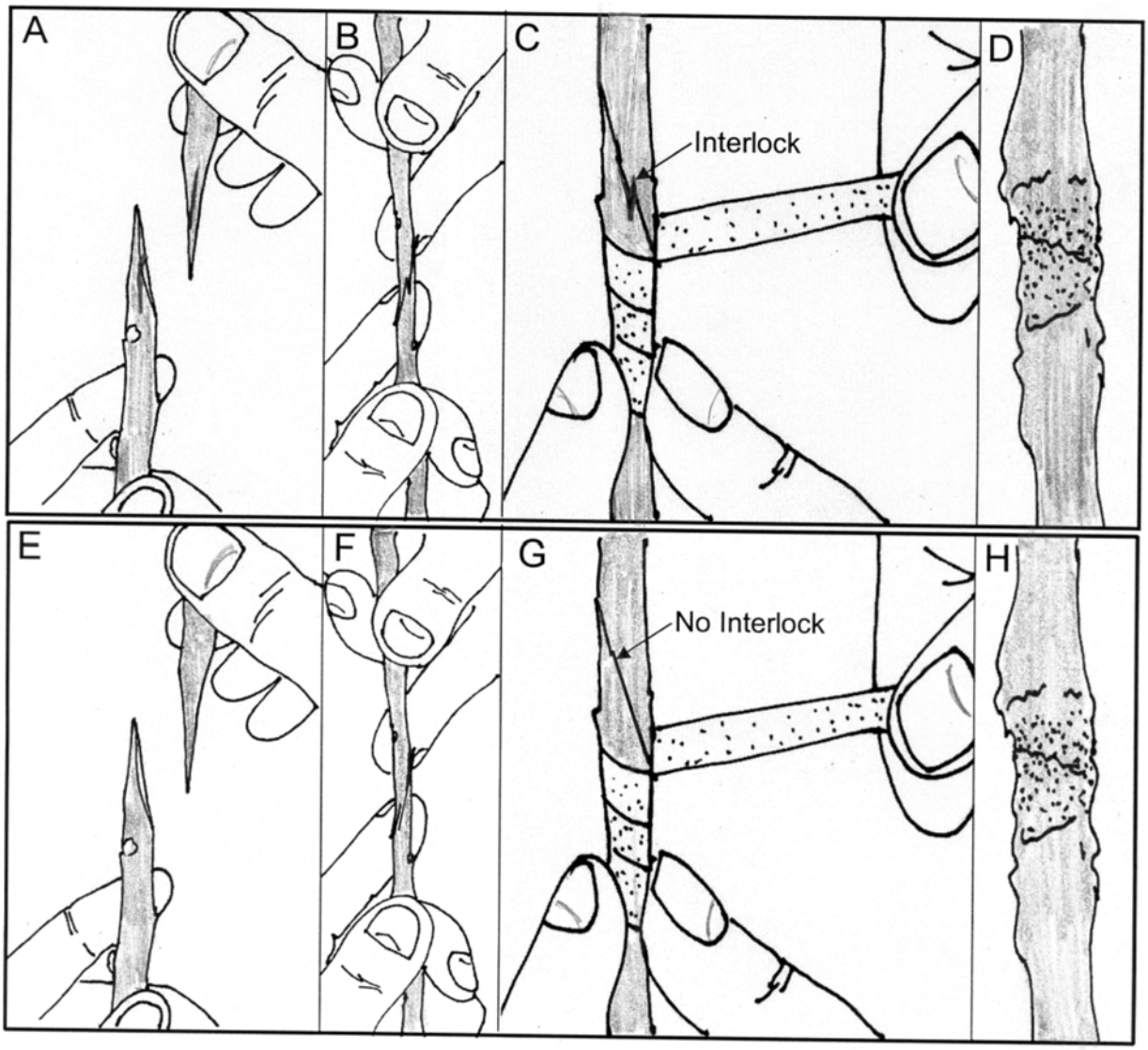

Fig. 13. Whip and tongue (A–D) and splice (E–H) methods of grafting. The whip and tongue method ensures the interlocking of stock and scion to facilitate a better graft union. See the text for details.

growth with mature, plump buds. Remove the leaves by snipping through the petiole (the stalk of the leaf) and leaving a petiole stub of about 0.25 inch attached to the budstick (the shoot with scion buds). You can store scion wood (budsticks) in a refrigerator, but only for a few days. It is best to use the budsticks immediately after collection.

For either budding or grafting, select only plants of known quality or performance free of insects, disease, and winter damage. For fruit trees, collect wood only from those in production to ensure that the kind and quality of fruit will be what you expect.

Methods of grafting and budding

Specific methods, appropriate seasons for grafting and budding selected fruit and ornamental plants, along with suitable rootstocks, are indicated in Table 1 (pp.17–18).

- *Splice (also called whip) grafting* is the simplest way to join a stock and scion. It is best suited for herbaceous plants in a protected location. The stock and scion should be less than 1 inch in diameter and of equal thickness. Make long, diagonal cuts of equal length on stock and scion. Fit cut surfaces of stock and scion together and use tape or other tying materials to hold the parts together. Additional protection with wax or similar materials is usually advisable (Fig. 13E–H). When the diameter of stock and scion are not equal, the scion should be placed to one side of the stock to ensure cambial contact on at least one side. Greenhouse tomatoes, eggplants, cucurbits such as zucchini, pumpkin, and squash are some examples that can be splice grafted.

- *Whip-and-tongue grafting* is one of the most common and useful grafts for woody plants. It is used for topworking and producing new plants, primarily deciduous trees. It works best with a stock and scion of equal diameter of less than 1 inch (preferably 0.25 to 0.5 inch; Fig. 13A–D).

  Make 2 identical cuts on both stock and scion. The first should be a diagonal cut like that of a splice or whip graft. Vary the length of the cuts based on the diameter of stock and scion, increasing in length with increased diameter. In general, the length of the cut should be 4 to 5 times the stock or scion diameter. Make cuts with a single knife stroke. Wavy cuts may prevent a satisfactory union. Make the second, or tongue cut, on the stock and scion by placing the knife on the surface of the first cut about half the distance between the pith (the center core of stem) and outer bark, or epidermis, on the upper part of the cut. Bring the knife down through the pith until it is opposite the base of the first cut. This second cut should not follow the grain of the wood, but should tend to parallel the first cut.

  When the tongues are cut, insert into each other until they are interlocked. Then secure the parts by wrapping tightly with tape or other tying materials. If tape is properly applied, additional protection with wax may not be necessary. If the scion is smaller than the stock, fit the tongues together so that the outside surfaces of stock and scion are aligned on one side only. Close alignment of the cambial tissues in the stock and scion are critical for grafting success.

- *Cleft grafting* (Fig. 10A–D) is used for topworking and should be completed before active growth of the stock. Scions are usually about 0.25 inch in diameter and have 2 to 3 buds. Stocks should be 1 to 4 inches in diameter and straight. Saw off the stock at a right angle in relation to its main axis of the branch. Make the cut so there are 4 to 6 inches below with no knots or side branches. Use a clefting tool (Fig. 11) or heavy knife to split the stock down the center for 2 to 3 inches (see Fig. 10A). Drive the tool in with a wooden mallet. Remove the cutting edge of the clefting tool and drive the wedge part of the tool in the center of the stock to open the split to receive the scions. Wedge open the branch after the scions have been prepared to avoid drying of the freshly split tissue.

  Prepare 2 scions. Cut the basal end of each into about a 2-inch-long tapered wedge. One side of the wedge should be slightly thicker. Make sure these long cuts on the scion are smooth and made with a single sweep of the knife. The wedge should allow stock-scion contact on each side of the stock, placing the narrow part of the wedge toward the center of the stock. Align the cambium layers of stock and scion without regard to outside surfaces. Remove the metal wedge of the clefting tool from the stock, which leaves the scions held snugly in place. Completely cover all cut surfaces with wax, including the splits down the side of the stock and the tip of the scion.

  If both scions grow, the healing of the large stock stub will be more rapid than if only one scion grows. However, one scion must eventually be removed. From the beginning, one scion should be dominant; keep the other small by pruning. After 2 or 3 years, prune out the smaller scion.

- *Bark grafting* can also be used for topworking with larger stocks (up to 12 inches in diameter) than for cleft grafting, but the scions should be similar in size (Fig. 9A–C). Several scions can be inserted around the stock. Cut the stock off as in cleft grafting, but do not split it through the center of the stem. Cut the base of the scion on one side with a long, smooth, sloping cut about 1.5 inches

long, going completely through the scion so that it comes to a point at the base. Make a vertical cut about 1.5 inches long through the bark on the stub of the stock.

Slightly loosen the bark at the top of the cut and insert the wood surface of the scion base next to the wood of the stock. Push the scion down in behind the bark to the extent of the cut on the scion base. Secure in place by driving 1 or 2 nails through the base of the scion into the stock. Cover all cuts and exposed surfaces with grafting wax. Since the union with this type of graft is weak for a year or two, the scions may need to be tied up for support after growth begins. For topworking, place scions every 2 to 4 inches around the stock stub. As for cleft grafting, the intent is usually for only one to remain. Train and prune the same as for cleft grafting as well.

- *Side grafting* can be used for topworking or producing new plants. Several forms of side grafting are used. The stub-side graft is primarily for topworking fruit trees with branches too small for cleft or bark grafting and too large for whip grafting. The other forms are mostly for producing new evergreen plants by grafting on small seedling stocks (Fig. 14A–J).

  ◊ Stub-side graft: Make grafts on stock branches which are between 0.5 and 1 inch in diameter. Make a cut in the stock at a 45° angle going about halfway through the stock. Cut the scion similar to the scion used for cleft grafting on one side. On the opposite side of the scion (opposite to the cut) make a shorter cut in the form of a wedge. Prepare the rootstock by opening one side of the stem as shown in Fig. 14C. Insert the scion into the cut on the stock. Little or no cut surface of the shorter cut should be visible on the scion. Cut the stock off about 6 inches beyond the graft. Cover the graft area, stock stub, and end of the scion with a protective compound such as wax.

  ◊ Side-veneer graft: Make a shallow cut, about 1.5 inches long at the base of the stock, directed slightly inward (Fig. 14A-E). At the base of this cut, make a short inward, downward cut to intersect the first cut, thus allowing removal of a piece of wood and bark. Prepare the scion with a long cut the same length and width as that of the first cut on the stock. Make a short cut on the opposite side of the base of the scion. Insert the scion in the stock with the long cut of the stock next to the long cut on the scion. Secure the scion by wrapping with tape or rubber budding strips. Cover the graft region with a protective material. When the graft union forms, cut off the stock just above the union.

  ◊ Side-tongue graft: Prepare the scion as for whip grafting. On a smooth place on the stock, remove a thin slice of wood and bark

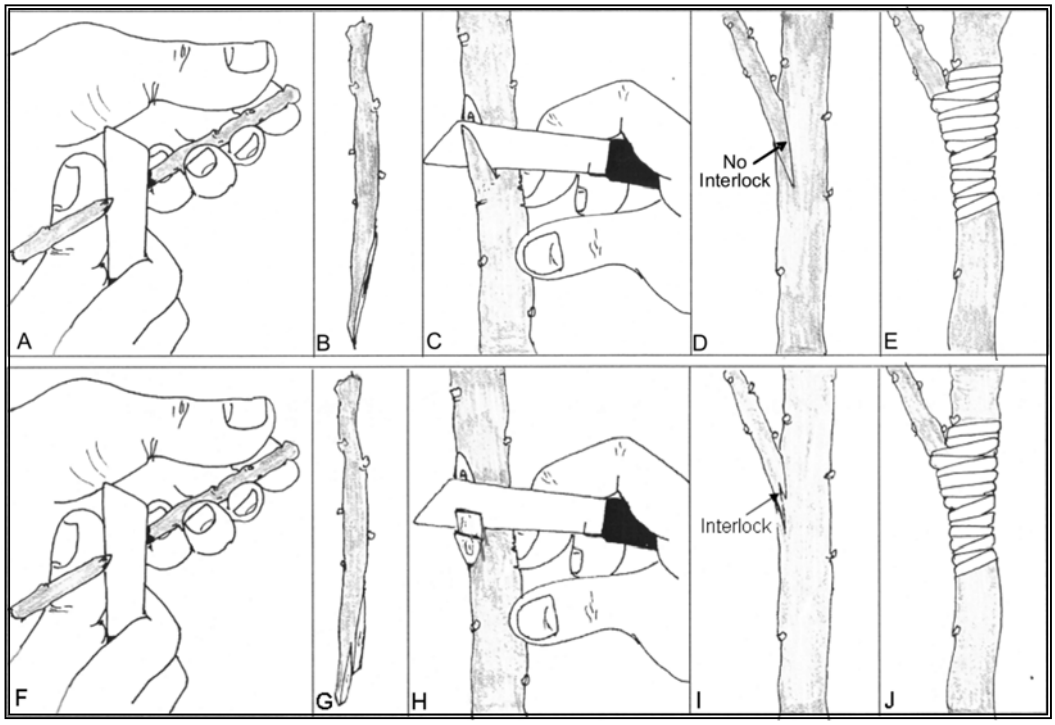

Fig. 14. Steps in side grafting without (A–E) and with (F–J) interlocking of stock and scion.

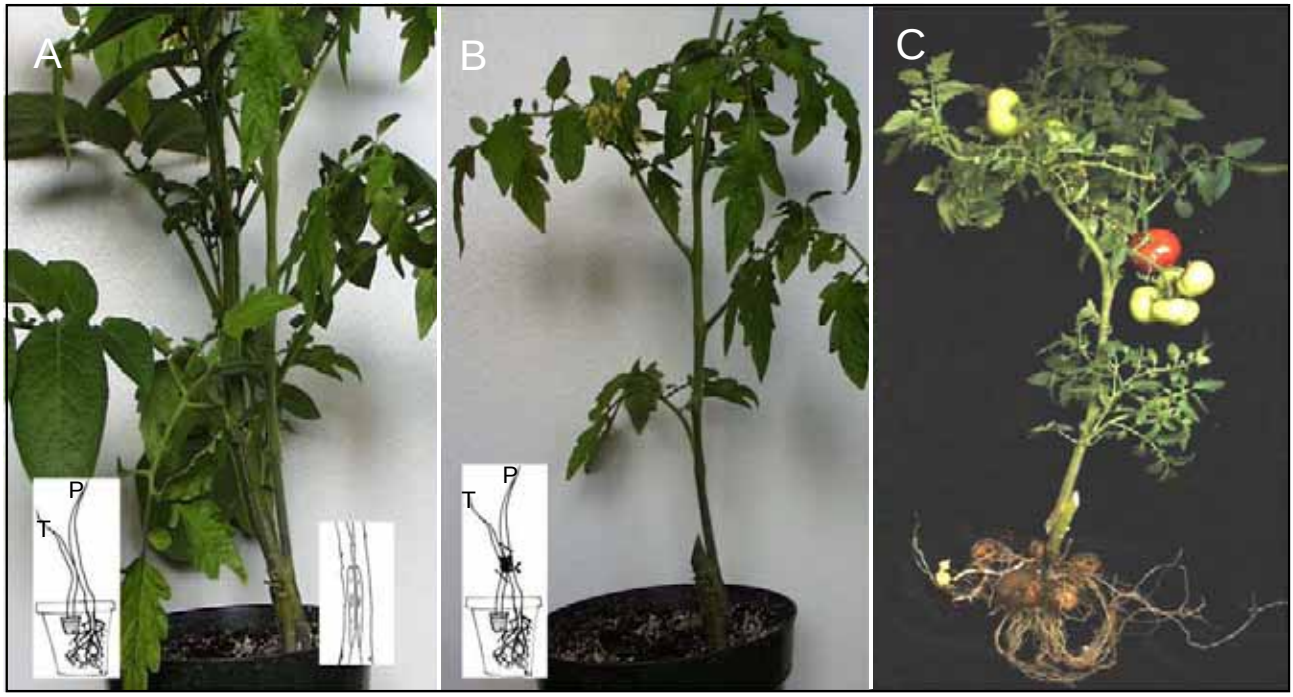

Fig. 15. Approach grafting of tomato on potato rootstock (T, tomato; P, potato): A) A seedling tomato plant raised in a cell pack is planted by the potato plant grown in a container. Both the plants are given an even cut as shown in the inset. B) Both potato and tomato plants are united using a parafilm wrap (see inset). Following the graft union, the potato stem is cut above and the tomato plant below the graft union, resulting in a combination of tomato as scion and potato as rootstock. C) A successful potato-tomato graft bearing tomato fruits and potato tubers.

about 1 to 2 inches long. Make a tongue cut by starting about one-third of the distance from the top of the first cut and progressing to the base of the first cut. Fit the tongues of stock and scion together; wrap the graft with tape or other tying material and add a protective covering to the grafted region. Cut off the stock above the graft following successful union (Fig. 14F–J).

- *Bridge grafting* is used to repair damaged bark areas at the base of a tree. Bark damage caused by cold, rodents, or implements may kill a tree if severe enough. If the trunk is not completely girdled, the tree can usually be saved by bridge grafting (Fig. 3 photo). Bridge grafting must be done when the bark "slips" just as active growth is becoming apparent in the spring. Select dormant 1-year-old scion wood long enough to bridge the damaged area. Make cuts like those for bark grafting on both ends of the scions, being sure that both cuts are in the same plane (Fig. 3A–D). Make a flap cut the width of the scion through the bark of the stock below the injured area. Pull the end of the bark flap loose from the wood and insert the base of the scion under the flap as for bark grafting. In a similar fashion, attach the top of the scion to the stock above the injured area. Attach scions to the stock about 3 inches apart across the injured area.

  If the tree is young enough to allow the trunk to bend in a strong wind, the scions must retain an outward bow after the graft is complete. This allows the trunk to bend without pulling the ends of the scions loose from the trunk. Cover all cut surfaces with protective waxes, making sure to seal the areas where the scion is inserted into the stock, particularly under the scion. Remove shoots that grow from scion buds. If trunk damage extends below ground level, the lower graft must be made on a large root. Uncover the root and proceed as if you were working on the trunk. When completed, re-cover the root with soil.

- *Inarching* is a repair technique that may be used instead of bridge grafting. Suckers growing at convenient locations next to the injured area, seedlings, or rooted cuttings planted next to the trunk are bark grafted into the trunk above the injured area (Fig. 3E–H). Cover the graft area with a protective material. Remove shoots which develop on the inarches. If the tree is on a dwarfing rootstock, the rootstock used for inarching should be of the same kind (otherwise the benefits of the original rootstock will be lost).

- *Approach grafting* is used to support a weak crotch in a tree or to graft together two plants while both remain on their own roots. For

giving support, two adjacent branches are joined together. For two plants on their own roots, the main stems are joined together. This method has the advantage of an uninterrupted flow of water to the scion from its own roots until the union is formed. Likewise, the rootstock receives manufactured food from its top during the graft union formation. Stock and scion or adjacent branches within a tree may be joined by the spliced method which uses single, long, smooth cuts on adjacent surfaces.

To begin approach grafting, remove a thin slice of bark of from the stem (see Fig. 15A inset) using a sharp knife at the place intended for establishing graft union. Bring the cuts together and use wrapping material to hold tightly in place. Cover the area with a protective material. If opposing tongues are cut on the face of the splice in a similar fashion as for side-tongue grafting, the method is referred to as a tongue-approach graft. In this case, the tongues are slipped together for added stability while healing. The other procedures are the same as for the spliced approach. Fig. 15 shows approach grafting of tomato on potato plants. When the rootstock and scion unite, the rootstock is cut above the graft union and scion below the graft union.

- *Four-flap (banana) grafting* (Fig. 16) is well suited for grafting plants with comparable diameters of 0.5 to 1 inch. To begin grafting, cut the

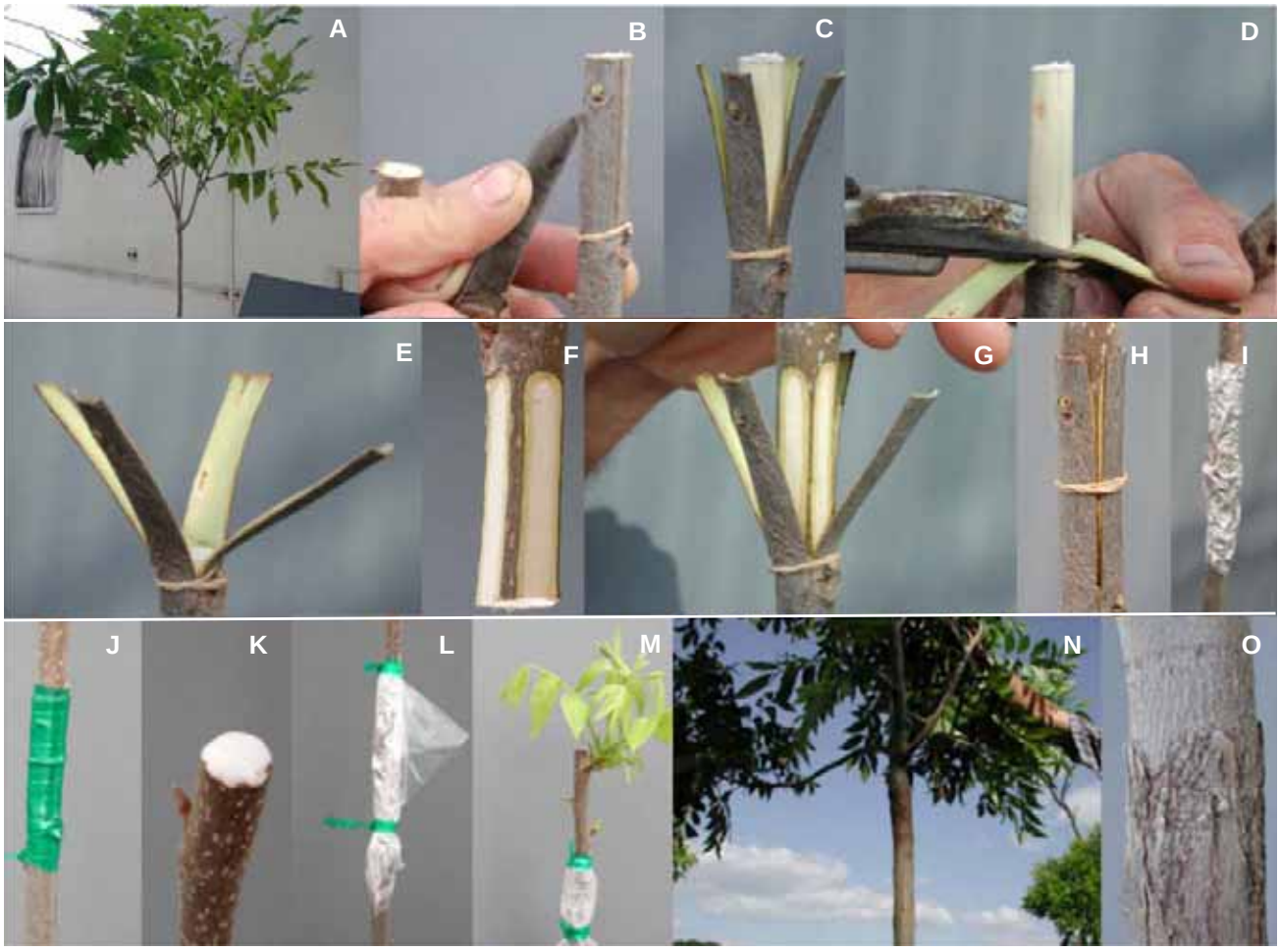

Fig. 16. Four-flap (banana) grafting is well suited for grafting plants with comparable diameters of 0.5 to 1 inch. Fully grown rootstock suitable for grafting (A). To begin grafting, the stem of rootstock is cut at the height intended for grafting (B). A rubber band is then placed around the stem and four vertical cuts are made on the scion (B, C). The bark is then peeled in a manner similar to that of peeling a banana fruit. The stripped wood is then cut and discarded (D, E). The bark on the scion is removed with four cuts 1 to 1.5 inch long (F). The prepared scion is then inserted onto the stock and the four flaps are brought in contact with the scion by rolling up the rubber band (G, H). The grafts are held together with plastic wrap and aluminum foil (I, J, L). The exposed cut at the top of the scion is sealed with glue to avoid desiccation (K). This method of grafting has a very high success rate due to maximized cambial contact between rootstock and scion. Restoration of growth on the scion of a successful graft (M), a fully developed grafted tree (N, O). (Courtesy of Larry A. Stein and Julian W. Sauls, professors and Extension horticulturists, Texas AgriLife Extension Service)

rootstock stem at the height intended for grafting. A secateur or a tree pruner is useful for this operation. Next, place a rubber band around the stem approximately 2.5 to 3 inches away from the cut end. Using a sharp knife, make four vertical cuts of 1–1.5 inches long on the scion. Peel the bark in a manner similar to that of peeling a banana fruit. The bark should slip easily from the wood, which is possible only in spring when cambial cells are actively dividing. Cut and discard the stripped wood, but retain the peeled bark with four flaps. Use a scion that is 5 to 6 inches long comparable in thickness to the stock. Remove the bark on the scion with four cuts each 1 to 1.5 inches long as shown in Fig. 16F. Next insert the prepared scion onto the stock (Fig. 16G–H) and bring the four flaps in contact with the scion by rolling up the rubber band. Cover the grafted area with aluminum foil or plastic wrap. Seal the exposed cut end of the scion with glue to avoid desiccation. This method of grafting has a very high success rate due to the maximized cambial contact between rootstock and scion.

- *Topworking* can be done by a variety of grafting or budding techniques. Trees less than 4 years of age can be topworked rapidly by T or chip budding or whip grafting. The branches should be less than 0.5 inch in diameter. For larger branches, use side, cleft, or bark grafts. Place graft or bud scions within about 18 inches of the main trunk of a tree. This means that large cuts are required on older trees. Insert buds on the side of a horizontal branch and the outside of a vertical branch to encourage outward growth. When the buds or grafts begin to grow, they may require support or pruning. Shoots will develop from the old or original parts of the tree. Unless you wish to have more than one cultivar or species on the tree, you must remove all these shoots eventually. Do not undertake this all at one time; removal should be gradual during the first year. Some shoots will continue to appear for 2 to 3 years. Fig. 17 shows a flowering crab apple topworked to an edible apple cultivar.

Fig. 17. A flowering crab apple tree topworked with an edible apple cultivar.

- *T or shield budding* (Fig. 18) is used to topwork or produce new plants. It is the most common budding method for producing fruit and ornamental plants in the United States. It works best on rootstocks of 0.25 to 1 inch in diameter with thin bark. It must be done when the bark slips. For summer and fall budding (July to early September), the preparation begins by early season removal of scion shoots while they are still soft and succulent. Select scions from dormant 1-year-old wood for spring budding and current season growing shoots for summer budding.

  To begin the budding process, find a smooth, branch-free area on the stock for insertion of the bud. If you are topworking, choose an area on the side of a lateral branch 12 to 18 inches from the main stem or trunk. If you are budding on seedlings to produce new plants, select an area about 6 inches from the ground. On similar-sized clonal rootstocks, insert buds 12 inches from the ground. Make an upward vertical cut through the bark for about 1.5 inches on the selected area. Next, make a horizontal cut to form a T with the vertical cut. As you make the last cut, hold the knife at an acute angle in relation to the upper part of the rootstock. This technique will open the bark (see Fig. 5) to allow easy start of the scion bud.

  Remove scion buds from the budstick in one smooth stroke. Start the cut about 0.5 to 0.75 inch below the bud, pass just under the bud, taking a sliver of wood with the bud, and extend about the same distance above the bud. The bud removed from the scion is now ready for insertion into the cuts made on the rootstock.

  To insert the bud, place the lower tip of the bud shield in the opening at the top of the T cut. When the opening is properly made, at the top of the T cut, the excised bud can be inserted in between the bark and the wood. Following insertion, push the bud down into the opening with the tip of the budding knife inserted in the shield above the bud. Slide the bud down so that the top of the shield is even with the top of the T in the stock. Wrap the bud in place with rubber budding strips by starting a self-binding loop just below the lower end of the bud shield. While stretching the rubber strip, make 3 to 4 loops below and above the bud, being sure to cover the top of the T. Insert the end of the rubber strip under the last wrap and pull tight. Cut off the top of the rootstock at a point just about even with the top of the T cut.

For fall budding, wait to remove the top of the rootstock until the following spring, just as growth starts. For spring budding, remove the top of the rootstock 2 to 4 weeks after budding. For June budding, remove the top of the rootstock in 2 steps starting 4 to 5 days after budding: 1) Cut 5 to 6 inches above the bud, allowing at least one leaf of the rootstock to remain above the scion bud; and then 2) about 2 weeks later as the scion bud begins growth, break the bud of the rootstock just above the bud union. After removal of the top of the rootstock, the rootstock may produce a number of shoots around and below the bud. Break these off as soon as they appear, except for June budding when these shoots should remain until the scion shoot is 10 to 12 inches long.

- *Chip budding* (Fig. 19) does not require bark that slips on either a stock or budstick. It can be done in the spring just as growth begins or in the summer at the same time as other budding techniques. Stocks and budsticks should be 0.25 to 1 inch in diameter. Remove the chip from the rootstock by making two cuts. The first is a downward cut at a 45° angle, going about 0.25 inch through the stem. The second cut starts about 1 inch higher than the first, going downward and inward until it connects with the first cut. Make similar cuts on the budstick to remove the scion, about 0.25 inch below the bud and 0.5 inch above the bud.

  Fit the scion to the stock so that the cambium layers of stock and scion match on at least one side but preferably both. Wrap the bud in place with plastic strips or tape to cover all cut edges, but leave the bud uncovered. An added precaution is to cover the area with grafting wax.

Fig. 18. T and inverted T methods of budding: A, B) removal of the bud, C) preparation of the rootstock by giving an incision in the form of an inverted T to facilitate lifting of the bark, D) insertion of the bud into the incision made on the rootstock, E) T method of budding, F) parafilm holding the bud in place. Insets: Insertion of buds into the cuts made on the scion. (Line drawing reproduced from PNW 496, 1996)

Fig. 19. Chip budding method. A) Removal of the bud along with the bark. B) Preparation of the rootstock by giving an incision to remove the bud from the scion. C) The bud is held in place with parafilm. Chip budding ensures better cambial contact and thus high union success rates.

Fig. 20. Patch budding method: A, B) removal of the bud, C) placement of the detached bud on the rootstock, D) parafilm holding the bud in place.

Cut the stock back as for T budding. Following successful union, cut the rootstock above the bud union.

- *Patch budding and related forms* are (Fig. 20) usually completed in the summer. These methods are suitable for plants with thick bark that renders T budding an unsuitable method. The scions used with these methods include a bud on a patch of bark varying from 1 to 1.5 inches around to a complete ring of bark removed from the budstick. The scion contains no wood behind the bark patch. Budsticks and stocks should be

approximately equal in diameter, ideally between 0.5 and 1 inch. The bark of both stock and budstick must slip readily (peel off easily).

The scion patch is best removed from the budstick using a special cutting tool with four blades fixed in a square or rectangle. When using this tool, you can remove an exact duplicate of the scion patch from the stock, and the fit will be perfect. Another common approach is to use a double-bladed knife to make the horizontal cuts on the budsticks and stock while using a single-bladed knife to make the vertical cuts. The scion-stock fit must be perfect at the horizontal cuts to achieve successful patch budding.

When removing the scion patch from the budstick, lift only the edges; remove the remainder of the patch by sliding sideways to break the woody connection between the bud and the budstick. If the entire patch is lifted off, this connection will be torn from the bud and the bud will fail to unite properly with the stock. When removing a budless patch from the stock and placing a duplicate scion bud patch with a bud is in its place, wrap the patch in place. If the stock bark is thicker than the scion, the bark around the edge of the patch may require trimming to hold the patch snugly in place.

Wrap the bud in place with tape, being careful to seal all cuts, but leave the bud uncovered. If wrapped adequately, other protection is unnecessary. An added precaution, however, is to use wax or other protective materials. Following successful budding and growth of the scion, cut the rootstock above the bud union.

Repair grafting

Tree repair is done by bridge grafting, inarching, or approach grafting. See the discussions related to these specific methods and Fig. 3.

Further reading

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Acknowledgements

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Revised in 2011 by G.N.M. Kumar, Associate Professor, WSU Horticulture and Landscape Architecture. All pictures and line drawings, unless otherwise specified, are by G.N.M. Kumar.

Table 1. Grafting and budding methods for the propagation of selected fruit and ornamental plants. The most appropriate season for propagation is indicated in the shaded area.

Common Name	Botanical Name	Budding			Grafting				Rootstock(s)*
		T	Chip	Patch	Whip	Side	Bark	Cleft	
Almond	*Prunus dulcis*	F							almond, peach, Marianna plum
Apple	*Malus domestica*	S,F			W		S,Su	S,Su	
Apricot	*Prunus armeniaca*	S,Su,F							apricot, peach, myrobalan plum
Arborvitae	*Thuja spp.*					W			
Avocado	*Persea americana*	S,Su,F							
Azalea	*Rhododendron sp.*					F			
Beech	*Fagus sp.*				F				
Birch	*Betula spp.*	F	F			W			*B. pubescence, B. pendula, B. platyphylla*
Butternut	*Jugulans cinerea*						S		black walnut
Camellia	*Camelia spp.*				W	W			
Carob	*Ceratonia siliqua*		Su						
Cedar	*Calocedrus decurrens*					W			cedar, Thuja
Cherry	*Prunus avium*	S,F	S,F						
Chestnut	*Castanea spp.*	S	W		W				
Citrus	*Citrus spp.*	S,F							citrus, *Poncirus* (Trifoliate orange)
Dogwood	*Cornus spp.*	F			W				
Filbert	*Corylus spp.*				W				
Fir	*Abies spp.*					W			
Fringe tree	*Chionanthus spp.*	F				W			
Ginkgo	*Ginkgo biloba*	S	S		W				
Grape	*Vitis spp.*	S,W			W				
Hackberry	*Celtis spp.*		S			S			
Hawthorn	*Crataegus*	F							
Hazelnut	*Corylus avellana*				W				
Hibiscus	*Hibiscus rosa-sinensis*				S,Su				
Hickory	*Carya spp.*			F			S		
Honeylocust	*Gleditsia triacanthos*	F			W				
Horsechestnut (buckeye)	*Aesculus spp.*	F			S			S	
Juniper	*Juniperus spp.*					W			
Kiwi	*Actinidia deliciosa*	F			W				
Magnolia	*Magnolia spp.*					W			
Maple	*Acer spp.*	Su,F	Su,F			Su			
Mountain ash	*Sorbus spp.*		F		F				
Nectarine	*Prunus persica*	Su,F	Su,F						peach, apricot, some plums
Oak	*Quercus spp.*				W	W			
Olive	*Olea europea*	F		F	W				
Pawpaw	*Asimina triloba*		S						
Peach	*Prunus persica*	Su,F							peach, apricot, some plums
Pear	*Pyrus spp.*	F			W				pear, quince
Pecan	*Carya Illinoensis*			Su					

Note: S, Spring; Su, Summer; F, Fall; W, Winter
*Scions are grafted or budded onto their seedlings where specific rootstocks are not indicated.

Table 1 continued. Grafting and budding methods for the propagation of selected fruit and ornamental plants. The most appropriate season for propagation is indicated in the shaded area.

Common Name	Botanical Name	Budding			Grafting				Rootstock(s)*
		T	Chip	Patch	Whip	Side	Bark	Cleft	
Persimmon, Japanese	*Diospyros kaki*				S				*D. lotus, D. kaki, D. virginiana*
Pine	*Pinus spp.*					W			
Pistachio	*Pistacia vera*	Su,F							
Plum, Prune	*Prunus domestica*	F							plum, peach, apricot, almond
Quince	*Cydonia oblonga*	F							
Redbud	*Cercis spp.*	Su							
Rhododendron	*Rhododendron spp.*					W			
Rose	*Rosa spp.*	S,Su,F							*R. multiflora, R. canina, R. chinensis, R. odorata, R. rugosa*
Shagbark hickory	*Carya ovata*			Su					
Spruce	*Picea spp.*					W			
Viburnum	*Viburnum spp.*					W			
Walnut	*Jugulans regia*	S,Su		S,Su	W				black walnut, Persian walnut, paradox walnut
Yew	*Taxus spp.*					W			

Note: S, Spring; Su, Summer; F, Fall; W, Winter
*Scions are grafted or budded onto their seedlings where specific rootstocks are not indicated.

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PNW496