

Propagating Avocados

Principles and Techniques of Nursery and Field Grafting



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Front cover: *A young avocado tree growing from a successful graft.*
Back cover: *Steps in bark grafting (topworking).*

Propagating Avocados

Principles and Techniques of Nursery and Field Grafting

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Propagating Avocados

HISTORICAL INTRODUCTION

Avocado propagators have made many advances since planting the first trees of *Persea americana* in California well over 100 years ago. As is usual with a new fruit tree industry, the first trees were all self-rooted seedlings—each was grown from a seed (sexual reproduction). Avocado seeds have great genetic variability, so seedlings do not come true to type. To establish a selection, you must graft a bud or group of buds from a selected tree onto any available rootstock, or root of a stem. This is asexual, vegetative, or clonal, reproduction, and can yield a fruiting variety with three major advantages: (1) much higher average fruit quality, (2) much higher average fruit production, and (3) uniform fruit for easier handling and marketing.

About 1910, superior avocado selections from Mexico and Central America began to be imported into California. Regional nursery operators began to graft avocado trees, just as they were already grafting citrus: rows of seedling rootstocks were grown in the field, and when these were a few feet tall, the growers made a T-shaped cut through the young bark and inserted a bud from the selected parent tree under the bark flaps, tying it in place with waxed budding cloth. This method was largely limited to the spring season, and by today's standards its success percentage was low. After the grafts had grown 2 or 3 feet, the trees were dug for sale, with the soil ball protected by a burlap (gunnysack) cover. The whole operation took 2 to 3 years.

About 1950, a radically new method of propagating avocados was pioneered by the late Walter Beck. Rootstocks were grown rapidly in containers under controlled greenhouse conditions. A much smaller rootstock was sliced off at an angle, a matching cut was made through a stem section from the selected parent tree, and the two cut surfaces were tied together to unite. The tree was pushed to saleable size in as few as 8 months. Beck called his method *tip grafting*, in contrast to the earlier side-stem

T-budding. Because there are now additional methods of grafting rootstock tips, it is better to refer to his graft method as *splice* (or *whip*) grafting.

In recent years, a modification of Beck's approach has become dominant in California. Rootstocks are still grown in greenhouse containers, but the splice graft has been replaced with the *small-cleft* or *wedge* graft, where the stock is cut transversely and the little trunk is split to receive a scion. The new procedure has proven to be more efficient and more economical.

About 1970, commercial nursery operators began vegetative propagation of the rootstock portion of the avocado tree. This practice developed because of the devastation caused by root rot and the need for stocks resistant to it. Avocado seedlings exhibit great genetic variability, and that means that parental disease tolerance can only be maintained by vegetative propagation. The stems of most avocados root poorly, but E. F. "Ted" Frolich of the University of California at Los Angeles designed a method for enhancing stem rooting by growing the stems in darkness. In avocados, asexual propagation of rootstock is usually referred to as *clonal*.

All these changes in avocado propagation have occurred within living experience. Venerated nursery operator Oliver Atkins not only has actively participated in the advances—he can even recall using mules for nursery weed control.

Experience with avocados confirms general horticultural experience and plant science logic in that successful graftage has three essentials: (1) the plant part being added must have at least one healthy bud, (2) the cambial layers of the two parts being grafted must be in direct contact so that they can unite, and (3) the stock and especially the scion (or bud) must not dry out before union is effected.

BASIC POINTS

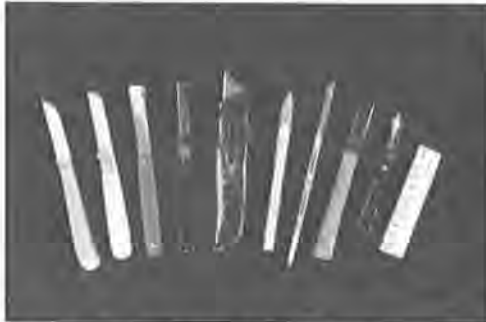


Fig. 1. Small grafting knives. Left to right: two grafting, two budding, three disposable-blade, and two TINA multiple-purpose knives.



Fig. 2. Large, handmade grafting knives.



Fig. 3. Handmade chisels, used primarily in notch grafting.

Safety

Razor-sharp tools are necessary for successful grafting, so you must exercise due caution. One example: when cutting a scion stick, hold the stick behind the direction of the knife stroke. Even among professional propagators, few remain long unscarred.

Power saws are especially dangerous, and need experienced operators. Moreover, the trees being cut down are themselves dangerous: the saw operator and anyone nearby should wear a hard hat, preferably with a protective facial shield attached. Hard hats are available with ear protectors built in, and these should be worn by anyone working near a power saw or chipper. In the absence of a facial shield, goggles can protect the eyes from flying sawdust and branches. Leather gloves and shin guards are additional safeguards.

Tools and Tool Care

Propagators are constantly adding new tools or refining old ones to increase efficiency. Which tool you choose will depend on the graft type and wood size. The knife or other cutting tool is basic. The best small knives (fig. 1) have thin, strong blades. Some are slightly beveled on both sides, but where perfectly flat cuts are wanted, beveling on only one side is better. The flat side of the blade should be the underside when cutting. Thus, the flat side of most smaller grafting knives is on the opposite side of the blade from that of large notch-grafting knives, because the smaller knives ordinarily shape the scion by cutting *toward* the propagator, while the larger notch scions are usually taper-cut *away* from the propagator. Horticultural supply house catalogs usually have a good selection of smaller grafting knives. So do some specialty knife centers.

Large knives (fig. 2) used in stump grafting have a similar blade style, but are usually custom made. All tools should be made of superior steel to hold an edge. Good current examples of such steel are O1 and W2, and stainless 154CM and 440-C. Certain chisels and hacksaw blades can be used as a source of superior steel. Cleft-grafting tools can be ordered through a catalog or custom made. Notch chisels (fig. 3) are best custom made, but you can also use available tools, such as a regular 3-inch chisel, a leather-cutting tool, or a thick, sharpened steel spatula. These three are apt to be slower to use. Where much sawing is involved, the superior speed saw is a good investment. Saw blades that fold into the handle protect the teeth from damage, and also protect the grafter from the teeth. Tools with stationary blades, such as chisels and some knives, should be kept in sheaths when not in use (fig. 4) to protect both the user and the blade. Brightly painted tool handles are much easier to find in leaves or other debris.

Clean your cutting and sawing tools periodically to remove sap, asphalt emulsion, sawdust, dirt, and grime. Use a scraping tool, a steel wire brush, or kerosene to remove sticky residues. In addition, it's a good idea to wipe the knife blade on a moist cloth to remove residue between cuts. Clean tools can help prevent the spread of plant diseases, especially sunblotch from symptomless "hidden carriers." After cutting into a suspect tree or a group of trees that have not previously supplied budwood, the careful grafter will disinfect the cutting tool. Common household bleach works well at one part in five parts water. This mixture can be used as a dip or in a spray bottle. Rinse in clean water. Ethanol (70 percent ethyl alcohol) also makes a good disinfectant.

Sharpening Grafting Tools

A sharp knife or other cutting tool is essential to efficient grafting. With cheap Exacto-type knives or the similar single-blade injector razors, you simply replace the blade when it becomes dull. But expensive grafting tools such as the TINA (far right, fig. 1), merit careful sharpening with a minimum of abrasion to maintain a keen edge.

The large knives and chisels used in stump grafting are generally made from very hard, tempered steel. Because of their size and hardness, they may require reshaping and sharpening by an expert using a grinder, belt, and buffer, perhaps once a year. Small grafting knives should have only a light touch-up on a flat sharpening stone as needed.

A strong lens will reveal the jagged edge that results from using a coarse stone to sharpen your knives. Such a stone will soon wear the knife out, because it tends to remove considerable steel in the sharpening process. Among the best hand stones are the Ceramic, Arkansas, Frictionite, and Washita. These are only slightly abrasive and with care will permit long service from a quality grafting knife. One could start sharpening with a medium-textured stone and finish with a fine-textured stone. Arkansas or Washita need a honing oil; ordinary mineral oil or #10 automotive engine oil can substitute for honing oil. The Ceramic and Frictionite are used dry. Some propagators like the results from using just one of these two types of sharpening stone. All stones should be cleaned when the accumulation of metal color is severe. Wash in warm water and detergent.

Sharpening is a skill acquired by practice, ideally guided by a person experienced with steels and sharpening tools. Secure the stone; do not try to hold it freehand. Place the blade to the stone at an angle of 20° to 25° and push it across the stone led by the cutting edge. You can hold the knife so that the blade travels across the stone with a partly sideways (oblique) motion. For double-beveled blades, alternate the sides with five or six strokes each, then finish with a single or double stroke on each side. Do not over-sharpen. Stroke across the entire stone in order to equalize its wear. Limit this razor-sharp knife to the actual grafting operation, using a general-purpose knife to sever bindings and for miscellaneous cutting. Between sharpenings, you can maintain an excellent edge by stropping on smooth leather.

Grafting Wraps

Wraps have two basic purposes: (1) to hold the cambial areas of stock and scion (or bud) together, permitting a strong union and (2) to prevent wound desiccation during the uniting process. There are various other uses, such as tying young grafts to supporting stakes.

The wrap should be somewhat elastic to permit subsequent growth expansion. Polyvinyl grafting tapes come in a variety of colors, widths, and thicknesses (fig. 5). Tapes vary from transparent, through varying degrees of opaqueness, to solid white or green. A somewhat transparent wrap can be a deadly heat trap; coat it with white latex paint after wrapping the graft. Tape widths usually vary from 3/8 to 1 inch. Tape thicknesses are commonly measured in mils (thousandths of an inch). A thickness of 4 mils (0.004 inches) is classified as light-gauge tape, tapes of 6 or more mils are correspondingly heavier. Ordinarily, the larger the graftage diameter is, the wider and thicker is the tape that you use. A 4-mil, 1/2-inch tape is commonly used for small-cleft or splice grafts; heavier tape is more difficult to draw tight enough for a moisture seal without injuring such small, tender grafts. A 1-inch tape of 6 or 8 mils is desirable for field topworking.



Fig. 4. Tool sheath (attaches to the belt).



Fig. 5. Various polyvinyl plastic tapes, as well as wrapping rubbers (upper left) and wrapping film (upper right).

Table 1. Stock sizes for various wrapping materials*

Graft type	Width and thickness of plastic tape				Other materials			
	1/2 inch, 4 mils	1 inch, 4 mils	1 inch, 6 mils	1 inch, 8 mils	Rubber band	Wrapping film	Flagging tape	Nails
Small cleft	VS				VS	VS	VS	
Splice	VS-S	M	M		VS	S-M	S-M	
Bark		L	L-VL	VL				VL
Cleft		M-L	M-L	VL			M	
Notch	-----	(no wrap used)		-----	-----	(no wrap used)		-----
Veneer		M-L	M-L	VL			M	M-VL
Saddle	S					S	S	
Side		M	M				M	
T-bud	S	M	M	VL		S-M	S-M	
Chip bud	S	M	M			S-M	S-M	
Patch bud		M	M	VL		M	M-L	

* Stock diameter legend: VS = very small (1/8–3/8 inch), S = small (3/8–1/2 inch), M = medium (1/2–1 1/2 inches), L = large (1 1/2–3 inches), and VL = very large (≥ 3 inches).

Other materials can be used (fig. 5), such as the new wrapping film and the cheap 1 3/16-inch surveyors' flagging tape. In the greenhouse, rubber bands about 1/4 to 3/8 inch wide and 6 to 8 inches long are generally preferred (table 1).

The greenhouse small-cleft graft and the field-cleft or bark graft are best wrapped starting from the top of the graft to bind the scion solidly in place, and working down. For other graft types, the direction will vary with personal preference. Wrap spirally over the length of the uniting surfaces to ensure a complete seal. This can be achieved by overlapping half of each previous wrap as you go. It is important to maintain a constant tension during the wrapping. Immature, rubbery wood should be wrapped less tightly to minimize binding injury. Finally, secure the wrap by slipping the end of the tape under the preceding turn (for a half hitch knot), and pull it tight.

For small-diameter grafts, remove the tape soon after the graft union heals to prevent restriction of growth. For medium- and large-diameter grafts, leave the tape on for about one year to help protect the graft union from breakage.

Selecting Graftwood

Just as a successful avocado variety requires superior fruit quantity and quality, so successful avocado propagation requires superior woods and techniques. Cut grafting wood from branches that have demonstrated high production of true-to-type fruit, on healthy, vigorously growing trees. Inadequate irrigation means inadequate graftwood. The best wood is on young trees, or on older trees that have been cut back severely to force strong upright new growth. However, extremely vigorous stems are more likely to have central soft pith that makes a scion more subject to desiccation. Select graftwood that is firm and not rubbery or pithy.

Each scion cut should have at least two, preferably three or four sound dormant buds. The best buds are large and plump (figs. 6, 7, and 8), with a healthy green color. Undersized buds are less likely to survive and grow. However, extra-large buds and plump buds from early winter through spring may be flower buds, which produce weaker vegetative shoots or none at all. Buds that are slim and elongate, often with tiny leaflike feathery tips, are not dormant; they will not store well and will take less successfully even when used fresh. Such immature buds have cambium that is more active and so might be considered better for propagation, but they are more vulnerable to desiccation. Therefore, avoid the rubbery stem ends of current growth

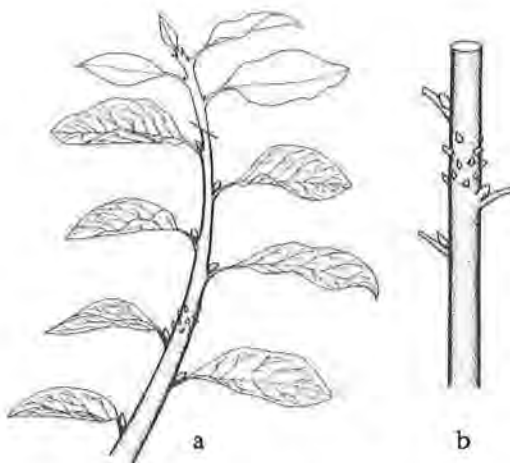


Fig. 6. A typical source of buds (a), and a knuckle, or whorl of buds (b).

(fig. 6a). In fact, cutting off this immature stem end a week or more ahead of time will usually hasten the growth and maturity of the more basal buds that will be better for grafting. Conversely, buds can be unacceptably past optimum (as shown by old-looking bark) or may have internal browning (indicating frost or other injury), and some buds may lack leaves, or several buds on the scion may abscise (drop off). All portions of the branches and limbs are potential sources of budwood, including mature terminal ends.

To select graftwood at a good stage, monitor the trees judiciously. In southern California, good propagation wood may be present as early as October or may not appear until as late as the end of January, but is usually best in December and January. Budwood may remain ideal for only 1 or 2 weeks, or it may be reasonably good until March. Optimum timing varies with variety, weather, and tree care. Reasonably good buds may be found several times during the year at dormant periods between tree growth cycles. When grafting is urgent but wood as described above is not present, and somewhat larger-diameter scions are usable, one may utilize the dense whorl of buds (*knuckles*, fig. 6b) marking the end of the previous season's growth. This type of scion produces a mass of shoots that you must prune to a single upright stem to develop a good tree.

Cut the scion long enough so that at the actual grafting time you can remove both deteriorated ends. Recut the apical end to just above a bud. The ideal budwood has three or more buds concentrated toward its upper end, with no side buds in the longer basal portion to cause irregularity in the grafting-cut edge. Budstick lengths vary with the type of graft, but should rarely be less than about 3 inches or more than about 8. A stem section ending in a terminal bud can make a satisfactory scion if well hardened; it would then be re-cut only at the basal end. After cutting a budstick, immediately clip off the attached leaves to minimize desiccation. The handiest tool for cutting and trimming graftwood is a pair of pruning shears.

Early morning is usually the ideal time to cut graft wood, in terms of both weather and tree physiology. Avoid periods of high heat, strong wind, or drought to minimize desiccation during the gathering process and a somewhat desiccated condition of the tree. After such drying adversity, wait a few days for good tree recovery. Conversely, avoid harvesting graftwood during rainy weather to minimize disease infections. Familiarize yourself with the sunblotch viroid to minimize the risk of its spread via budwood.

Storing Graftwood

Avocado wood is probably best used immediately after cutting, but often it must be stored. Cutting a large quantity of wood at one time may be most efficient. The optimum time for bud collection may not coincide with the optimum time for grafting, or the only budwood available may be far from the grafting site, or unfavorable weather may interfere, or illness or some other unforeseen snag may occur.

The budsticks can be stored for 2 or 3 months at about 40°F in sealed, medium-weight polyethylene bags. With thinner polyethylene or for longer storage, use double bags. Graftwood storage life can be extended by using a mild fungicidal dip, such as Captan, or by lowering the temperature slightly, but be certain that normal storage temperature fluctuations do not reach the freezing point. You can provide some added protection against brief freezing by wrapping the bagged wood in newspaper or ordinary paper bags, since the life processes in the living wood release a bit of heat. This heat, plus gas and moisture, means the maximum desirable number of budsticks in each bag is about 50. Wet wood should be surface dried before you



Fig. 7. Large scion wood for notch grafting.



Fig. 8. A graft partially bound with wrapping film.

place it in cold storage. In the absence of suitable refrigeration, larger grafting wood has been successfully stored for months in a cool, shaded outdoor area, in a box lined with several layers of wet newspaper and covered with a wet blanket or similar material. As many as 400 sticks per field orange box have been successfully stored by this method. Check the wood at least weekly, depending on the weather, and keep it moist. For overseas budwood shipment, the scion tips can be coated with wax or some other nontoxic seal, and moist moss or paper toweling can be placed in the polyethylene bag. However, excess moisture can be as harmful as deficient moisture.

The length of time budwood will keep depends not only on the storage conditions, but also on the wood diameter. Small-cleft wood, up to 1/4 inch in diameter, is often intended for grafting the same day that it is cut; it can be stored for a few days, or at most a very few weeks. Larger scions, such as for bark topworking, can keep for months. The still larger notch-graft scions can remain viable for more than a year; even when the buds have meanwhile grown out 1/2 inch or more, successful notch grafts can be made, if the growth is trimmed back and the cuts are sealed. There are also varietal differences. For example, compared with Hass, Gwen wood of a similar diameter usually is firmer and so stores better.

Before the actual grafting operation, graftwood stored in polyethylene should be transferred to a box lined with wet newspaper and covered with a heavy wet cloth or similar material. Polyethylene is a heat trap that can kill wood within minutes upon exposure to the sun. Therefore, keep wood shaded, as in a paper bag, preferably one with a thermal lining. Shade the bag itself if practical.

COMMERCIAL NURSERY PROPAGATION

Greenhouse Environment

The Brokaw Nursery maintains a night temperature of about 55°F and a day range of about 72° to 80°F. This is somewhat cooler than would be required for maximum growth of young avocado plants, but has several advantages: delayed plant crowding, sturdier plants, and lower night heating costs. Relative humidity is kept above 55 percent. Some nurseries prefer a higher temperature for more rapid seedling development.

Seedling Rootstocks

The development of clonal stocks, especially with uniform tolerance of root rot, has minimized the importance of seedling rootstocks. Of the three horticultural avocado races, the West Indian is best for salinity tolerance. Unfortunately, in its pure form it is too tropical to thrive in our cool winter soils. The Guatemalan race has some salinity tolerance and produces vigorous seedlings, but the Mexican race is generally used for California stocks because its trees produce larger numbers of fruits with greater seed ratios, and together with greater cold hardiness this makes it a surer source of annual fruit; and provides a hedge against basal stem injury of newly planted trees in freeze years. Its seedling roots also average more resistant to



Fig. 9. Vermiculite seedbed being planted with seeds that are end-cut for better germination.

chlorosis than Guatemalans, and apparently to *Dothiorella* disease and *Verticillium* wilt. Topa Topa has been the most popular source of seedling stocks because it germinates uniformly and is unusually vigorous for a Mexican variety. Individual nursery operators may have other, individual preferences that are quite satisfactory where root rot or other adverse conditions are neither present nor likely.

Seeds are commonly planted in the greenhouse during the autumn Mexican harvest season. Planting can be delayed for months if necessary, using cold storage similar to that for grafting wood; there will be a gradual decline in germination percentage over time, especially of somewhat immature seeds. Seeds that have been thus chilled will subsequently germinate more slowly and unevenly unless they are scarified. To scarify, cut off the top 1/2 inch or so (fig. 9), which will facilitate removal of the seed coat. A thin second slice off the base of the cotyledons can enhance both seed coat removal and germination rate. Even unchilled seeds sometimes benefit from scarification prior to planting. Cutting into the seed increases the risk of disease infection, and a fungicidal treatment may be desirable. You can enhance germination of somewhat immature seeds by soaking them in gibberellic acid at 500 to 1,000 ppm, but the resulting spindly stems may be less desirable for propagation.

After being removed from the mature, ripe fruit and washed, avocado seeds are sometimes dried to expedite removal of the seed coats. But the avocado embryo is much more exposed to desiccation than are those of most plants, and will survive only a few days at normal room temperature and humidity. On the other hand, the avocado embryo also has exceptional need for good aeration. Therefore, you should plant it at the soil surface with the tip of the seed showing (fig. 10). The seed is correctly oriented as it hangs on the tree: the embryo shoot is toward the stem end, the root toward the bottom of the fruit.

Seeds can be germinated acceptably in sawdust or sand, with careful attention to optimum moisture maintenance. This is easier with newer materials such as vermiculite or a perlite-peat moss mixture (figs. 9 and 10). At the University of California at Riverside, we use UC #2 soil mix, which gives a good balance of adequate drainage and adequate water retention, based on 1/2 sand, 1/4 peat moss, and 1/4 nitrogenated redwood compost, plus added nutrients. All ingredients are sterilized with steam or methyl bromide. Seedlings that show beginning healthy development of both shoot and root can be transplanted into a suitable soil mixture in the final, large containers for grafting. Instead of using a seedbed, nurseries now commonly plant the seeds in plastic liners or seedbags, about 2 1/2 by 9 inches (fig. 11), with perforated bases for drainage. There is some loss to germination failure, but these small containers fit about 25 plants per square foot, making efficient use of greenhouse space. Avoid harmful crowding by sorting the developing seedlings for graftable size as needed. Graft right in the liners. Greenhouse plants will be graftable about 6 weeks after seed planting. Discard weak or off-type plants, since they seldom develop into good stocks.

Clonal Rootstocks

Until about 1977, practically all of California's commercial avocado trees grew on sexually produced seedling rootstocks; only the fruiting tops (Fuerte, Hass, etc.) were asexually produced. Since then, some half-million trees have been planted on clonal stocks, imparting to roots the same advantage as asexual tops: genetic uniformity. Today, about half of our commercial stocks are clonal.

Clonal rootstock uniformity is most important for consistent resistance to *Phytophthora cinnamomi* root rot. Salinity resistance is now available in the



Fig. 10. Plastic seed bags containing individual seeds that germinate through a perlite surface mulch. Note the exposed seed tips.



Fig. 11. A flat of good seedlings selected from a group such as that in figure 10.



Fig. 12. Metal "choking" ring clamped on the base of an etiolated rootstock clone. The wrapping rubber just below marks where the clone was grafted onto the nurse seedling.

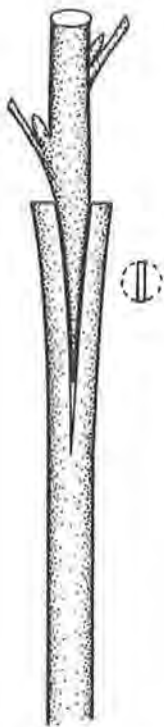


Fig. 13. Shaping and positioning for a small-left graft.

Borchard clone. Other useful resistances may be identified in the future. Some are known to have a dwarfing effect, and a true dwarfing stock would probably merit clonal propagation. Another possibility is a dwarfing (clonal) stem interpiece, perhaps on a (clonal) root-rot resistant stock. The overriding importance of *Phytophthora cinnamomi* means that other desirable stock traits, including favorable fruit quality and quantity, may best be sought among clonally propagated root-rot resistant lines.

Frolich method. Practically all commercial clonal rootstocks now produced in California and elsewhere are based on the etiolation method developed by E. F. "Ted" Frolich, formerly of the University of California at Los Angeles. Vigorous seedlings are grown from large seeds in containers of perhaps 1 quart, as a temporary nurse root system. Each seedling is grafted at a young age, and just above the soil line, to a clone that will become the tree's stock (usually chosen for its resistance to root rot). When the graft begins to grow, a single bud is retained, and the plant is transferred to a darkened chamber. Here, further bud growth will be elongate, lacking chlorophyll—the *etiolated* condition most conducive to avocado stem rooting. When the grafted shoot reaches a height of 8 to 10 inches, it is removed from darkness and enclosed in a cylinder about 6 inches high that is then filled with vermiculite, peat moss-perlite, or some other moist rooting medium. The shoot tip continues to elongate, developing normally in the light above the cylinder soil. After the shoot completes a growth cycle and hardens off, the etiolated stem base is cut from the nurse seedling and the severed plant is transferred to a humidity chamber to complete its rooting. Then the plant is grafted to the desired fruiting variety by standard methods and grown indoors for 6 to 10 weeks before transfer to a shadehouse, or it can be transplanted to a field container and grafted outdoors. To keep the plant healthy, leaves should be retained on the rootstock stem until the new graft is leafed out. In essence, the method requires double grafting: first to establish the clonal stock, and then to establish the (clonal) fruiting variety, with rooting of the stock encouraged by darkness etiolation. The double-grafting method works most efficiently with a greenhouse, but is possible outdoors.

Different researchers and nursery operators have come up with various modifications of the Frolich method. Rooting hormones, especially indolebutyric acid (IBA), are often added in solution or as powder to cuts in the base of the etiolated stem. Containers and rooting media have varied widely. Individual experience has led to some high success rates.

Brokaw innovation. A modification at Brokaw nursery was different enough to be patented, and propagators can arrange for sublicensing. Its major advantage over the original Frolich method is the more rapid development of saleable trees.

The nurse seeds are planted about one-third the way up a top-folded plastic bag about 2 3/4 inches in diameter and 12 inches in length. After reaching a height of 8 to 10 inches, the nurse seedling is grafted to the chosen rootstock as before. The rootstock stem grows in the etiolation chamber to a height of 12 to 16 inches. Then the plant is removed, a loosely-fitting metal ring is clamped near the stock-graft base (fig. 12), and the bag is extended to its full length and filled with more rooting medium. The metal ring, or weaning girdle, gradually constricts as the plant grows, killing the nurse seedling in a year or so; this extended period of dependence on the nurse root has caused a few problems for replants in soils with root rot infection, but has reportedly now been rectified. Other girdling devices are satisfactory if wide enough to prevent overgrowth and so reestablishment of the nurse-graft connection.

Other clonal methods. Layering also involves etiolation, and is usually done outdoors. Rootstock stems about 3/4 to 1 inch in diameter are pinned down

horizontally while still attached to the mother plant, and covered by about 4 inches of moist peat moss, fine bark, or other porous organic medium. Each good bud can produce a vertical shoot that emerges above its etiolated base, has a growth cycle, hardens off, and can then be severed from the mother stem and planted as a partly rooted cutting.

Ordinary cuttings of young stems from some avocado lines root fairly well in a mist chamber, with bottom heat and rooting hormones. Air layering (*marcotting*) has been successful, but not as a commercial procedure. Tissue culture is of increasing research interest, but has not as yet made any real contribution to commercial avocado propagation.

Grafting Methods

Each type of grafting technique is best suited to a certain set of conditions. Table 2 gives the appropriate stock size for each technique, and indicates where it is used the most—in the greenhouse, the nursery, or the grove.

Small-cleft. Most avocado greenhouse propagation in California today uses the small-cleft graft (figs. 13 and 14), also referred to as a *wedge* or, more ambiguously, a *tip* graft. Compared to the larger, outdoor cleft grafts, in which only one side of the scion matches its cambium with that of a much larger stock, both sides of the small-cleft scion usually match with the cambium of the similar-diameter stock. The method is conducive to speedy grafting; a talented propagator can make 600 or 700 grafts a day, with a success rate of 90 percent or better.

Suitable scions are about 3/16 to 1/4 inch in diameter. After wiping the scion clean, shape its base into a wedge by making opposite, flat, tapered cuts 1 to 2 inches long. For each scion, select a vigorously growing rootstock with a matching diameter 4 or 5 inches above the soil level, where you cut it off horizontally. Leaves below this point can be left to strengthen the plant; later, any suckers should be removed immediately. Split the stub down the middle a little further than the length of the scion wedge, and insert the scion into the cleft with the cambiums in contact on both sides. Stocks and scions of unavoidably unequal size may still be grafted successfully. If the scion is smaller, match the cambium on one side only. If the scion is larger, taper it on one side to fit and match it on the other side. A scion only a little larger may be matched on both sides if you cut shallower wedge-tapers.

Then wrap the union, generally with a special rubber band called a *budding rubber* about 5/16 inch wide and 7 inches long. Plastic 4-mil tape about 1/2 inch wide is also used. The wrapping covers the cut surfaces at the top of the union, so



Fig. 14. The rootstock has been split and the scion has been taper-cut for small-cleft graft.

Table 2. Graft type and usage*

Graft type	Location			Stock size (Inches)					
	Greenhouse	Nursery	Grove	1/8	1/4	1/2	1	2	4+
Small cleft	■			■	■	■	■	■	■
Splice		■	■		■	■	■	■	■
Bark		■	■					■	■
Cleft			■				■	■	■
Notch			■					■	■
Veneer		■	■					■	■
Saddle	■				■				
Side		■	■					■	■
T-bud	■	■	■			■	■	■	■
Chip bud	■	■	■			■	■	■	■
Patch bud	■	■	■			■	■	■	■

* Legend: ■ = frequent use, ■ = moderate use, and ■ = infrequent use.

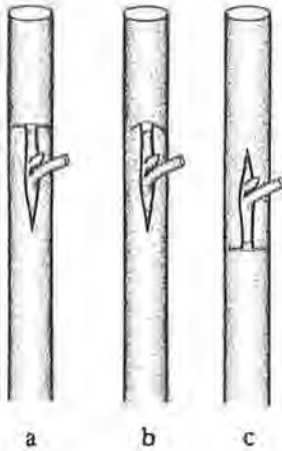


Fig. 15. Shield bud or T-bud (a), modified shield bud (b), inverted shield bud (c).

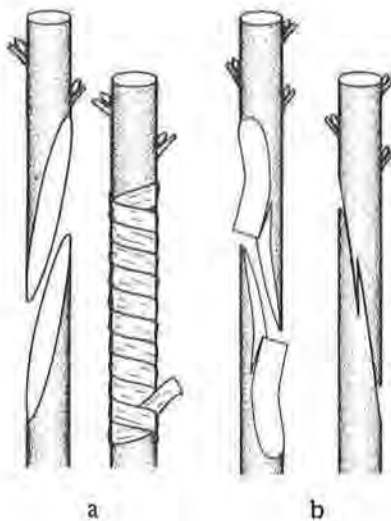


Fig. 16. Standard splice (a) and whip-and-tongue splice (b).

no sealant is necessary. The tip of the scion is sealed, usually with asphalt emulsion (*bitumen*), which is also applied to any areas where a cut surface may be exposed to desiccation. The scion should begin to grow in 4 weeks or less.

Shield bud or T-bud. In "budding" forms of grafting, you only graft a single bud onto the stock. The two names *shield bud* and *T-bud* refer respectively to the thin piece of cut wood (the shield) to which the bud is attached and to the double incision (T) made in the stock stem (fig. 15a). The former facilitates the insertion of the bud into the latter. Shield budding was the first significant commercial method of asexual avocado propagation used in California. It is still used sometimes, such as when budwood is scarce and expensive, or rootstocks become too large for small-cleft or other juvenile stock grafting. The successful "take" percentage is seldom as high as with small-cleft, and shield budding is limited to the time when bark is slipping.

Propagators usually cut the shield bud from larger-diameter wood than small-cleft scions, sometimes larger than the stock to which it will be grafted. The shield has a healthy bud and the underlying splinter of bark and wood (with the essential cambium layer in between). It is cut from the budstick with a sharp knife, preferably in a single stroke, beginning about 3/8 inch below the bud and ending about the same distance above it, the central main part of the shield cut parallel with the stick surface. The wood is cut thick enough to be firm. It is very important that the bud be healthy, large, and mature. For larger stocks, use larger bud shields and buds to avoid the bud becoming engulfed by callus.

Shield-bud stocks have a wide range of diameters, but commonly measure about 1/2, or 1 inch or larger in the field. A vertical cut about 1/2 inch long is made through the bark. At its top, a second cut about 3/8 inch long, either arcing downward or horizontal (fig. 15a and 15b), completes the T. You then insert the bud shield into the vertical flaps, beginning at the top. Wrap with a rubber band or with the 4-mil polyvinyl tape used for small-cleft grafts, leaving the bud exposed. The new, disintegrating wrapping film can be applied carefully as a total bud cover to further reduce desiccation and to exclude water. At grafting time or within the next couple of weeks, force the bud by cutting off the stock stem above it. The cut can be high enough to leave several leaves above the bud for better plant health, but monitor it regularly for sucker growth. Bud grafts require considerable time before they become firmly anchored; use a plant stake, and maintain a firm tie until you are sure of a strong graft union.

A modification known as *inverted shield bud* (fig. 15c) puts the horizontal cut at the bottom instead of the top of the vertical bark cut. The bud shield is inserted from the base. Under conditions of excess moisture, this modification minimizes the possibility of harmful water accumulation around the bud.

Splice or whip graft. Historically, as avocado propagation moved indoors, the shield-bud also moved indoors. But then, especially as propagators began to use smaller rootstocks, budding largely gave way to the usually more efficient splice grafting—originally referred to as tip grafting. Splice grafting has in turn been largely superseded in California by the still more efficient small-cleft grafting. However, some propagators may prefer a splice method.

A rootstock, usually 1/2 inch or less in diameter, is severed a few inches above soil level with a smooth slant cut about 2 1/2 inches long. The scion is sliced to match and the two cut halves are tied together with the standard rubber band or wrapping tape (fig. 16a). As with the small-cleft graft, scion and stock of similar cut diameter have the advantage of providing cambial contact on both sides. A scion larger than the stock can be used if you slice off one side of the scion to match diameters with

the stock and then match cambiums on the other side. A scion smaller than the stock can also be used, with contact on only one side, but the tight wrapping may center the scion so there is no cambial scion-stock contact. To minimize this tendency, make sure to wrap the graft in the direction that will push the stock and scion cambiums together.

The scion should have at least two good buds. To reduce the possibility of desiccation, this bud section above the uniting cut sections should be as short as possible.

A modification of this method that requires more time but provides a firmer union, is the *whip-and-tongue* (fig. 16b). An extra, vertical cleft cut is made down the middle of both scion and stock to permit more solid attachment. This procedure allows you to have both hands free while wrapping, an advantage especially for the beginner.

The straighter the scion is, the better. Slightly curved scions can take successfully; they are best taper-cut on the convex side, and cut back to an upper-side bud, which can grow out into a straight vertical stem. When the stock also is curved, as is more likely with field framework grafting, convex-side cutting of both tapers will straighten the graft.

Miscellaneous greenhouse grafts. Individual propagators may prefer various modifications of these basic graft types. Personal aptitude and circumstances may justify deviations from the described procedures.

An example of a different approach is the saddle graft (fig 17.). Here, the stock cut is wedge-shaped, and the scion is cut to match. The cut lengths should match closely. For the inverted saddle graft, the scion is the wedge and the stock is cut out to match. This procedure differs from the small-cleft graft only in that, where the stock is split in preparation for a small-cleft graft, a wedge of stock is removed in preparation for the saddle graft. Other modifications are possible. In any case, the union must be wrapped as indicated for other graft types.

Post-graft Procedures

Graft care. Assuming suitable plant materials and proper technique, desiccation is the greatest hazard to the successful take. In cool climates or in the cool part of the year, new grafts may need no special protection. Greater safety can be ensured by covering the bench of grafts with a polyethylene tent that hangs down far enough to maintain higher humidity but that permits some air circulation. The tent can be removed in 1 or 2 weeks, after the graft has healed. Under hotter conditions, the greenhouse will have to be made more opaque with whitewash. For only a few grafts, the tent and whitewash can be replaced with individual polyethylene sleeves, each covered by a light-colored paper sack. The larger tent is labor-saving and also permits easier monitoring of the grafts. Maintaining optimum soil moisture is of critical importance.

In about 5 weeks, most of the grafts will have pushed out 3 or 4 inches. If they have started growing vigorously, as shown by size and a commonly reddish rather than grass-green stem color, they can be placed outside for further growth and initial hardening in 50 percent shade (fig. 18). After at least 2 weeks here, harden them off in full sun for another 2 weeks or so, and they will be ready for potting up. You might plant the rootstock seeds around October; graft the stocks around December; place the young grafts in a protected area outdoors at about the end of January; in the open around the middle of February; and transplant them around the beginning of March. Different, staggered timetables may fit individual needs, and will provide more flexible workloads.

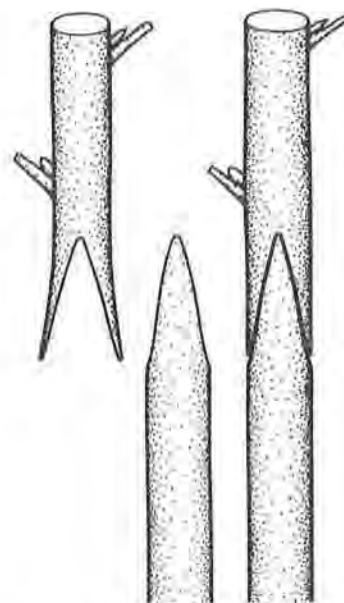


Fig. 17. Shaping and positioning for a saddle graft.



Fig. 18. Young trees hardening in a shade house.



Fig. 19. Transplanting young trees into field containers.

Transplanting to final containers. Trees are usually transplanted to large outdoor containers, from which they will be planted commercially, in spring after the danger of frost is past; earlier transplants need outdoor frost protection. A suitable container is 10-mil (.01") polyethylene with an ultraviolet inhibitor, formed 17 inches tall and 7 inches wide, parallel-sided and open-ended for drainage and economy. The container is generally used once. One different style made from the same material is shorter and has a closed bottom, and another made from considerably heavier material and reused has a round, 1-inch top collar and is fluted to the base to facilitate removal of the soil ball. Others are available. Black containers usually are cheapest; in climates prone to very hot sun, thin coat of whitewash applied to the container surfaces prevents soil ball damage from excess heat.

The containers can be filled in place outdoors, from soil in a wheelbarrow or other container on wheels. You can speed the filling process by using portable frames that guide the soil into four containers at a time. Sometimes, containers are filled in a potting shed. The containers are usually in rows only two deep to facilitate such operations as filling, weeding, suckering (removal of stock shoots), staking, and tying, and to minimize plant shading. In other situations, rows four deep may be more efficient. The light-advantage may be better if the rows run north to south instead of east to west. The soil mix is a compromise between what is needed for good drainage and for moisture retention. One good mix is UC #2. Brokaw Nursery uses a 60 percent sawdust, 20 percent sand, 20 percent sandy loam soil. There are many other satisfactory mixes.

Remove the grafted plant from its small growing bag (*liner*) by slicing off the bottom to prune curved roots if present, and then slitting the plastic bag and stripping it away from the young root ball. The root ball is then placed in a suitable hole drilled or otherwise formed in the field container (fig. 19). The transplant is watered as soon as feasible and then as needed, perhaps two or three times per week. Large-scale operations can save much labor by watering via a microtube drip system, preferably with constant fertilizer feed. About 1/2 gallon of fertilized water is applied at each irrigation; this should exceed the plant's transpiration needs enough to provide the desirable leaching of salts from the soil in the container.

Staking and tying usually begin soon after the young graft is transplanted. It will then grow in the nursery grounds until it reaches a height of at least 2 feet and completes at least one growth cycle (fig. 20), when it is ready for commercial planting. This may be in late summer, but more commonly it is the following spring, about a year after transplanting.

Propagation without a Greenhouse

Before about 1950, greenhouse propagation of avocados was almost unknown in California. Now as then, seeds can be planted outdoors close together in rows. Outdoors, a surface mulch of sawdust, straw, or peat moss preserves moisture and prevents surface crusting. Successfully germinated seedlings are then placed directly into the large field containers. From the usual fall seed planting, the outdoor seedlings will grow to graftable size by about the following midsummer. Overwintering in a lathhouse or under saran shade cloth will reduce frost danger, protect the young plants from wind, and permit better growth.

Budwood selection is more critical when grafting outdoors. The wood should be more mature to survive greater desiccation and, perhaps, slower union. Clues to this maturity include a somewhat larger size, firmer wood, plumper buds, and more of a yellow cast to the green bark stem. Some suitable budwood from hardened spring growth may be available by July, when the rootstocks from planting the

previous fall or early spring planting of stored seeds should be ready, and grafting will be reasonably successful in cooler climates. The wood should improve into the fall season, reaching its prime about December. The ideal grafting time is after the stocks begin spring growth, about March, so winter-hardened budwood must be pre-cut and stored.

A scion diameter of 1/4 to 3/8 inch is good, but larger diameters can be used. The small-cleft graft also works well outdoors, or you can use the splice graft or others. The shield bud is less satisfactory outdoors in California, since the single bud is often abortive in our dry climate. Leaves on the stock stem help to minimize plant setback, so the seedling is usually cut at or above 12 inches, leaving about five healthy leaves. However, this practice increases axillary stem suckering; routinely pinch suckers back to minimize their competition with the new graft. When the graft is growing well, completely remove every sucker. Immediately after grafting, protect the scion and stem from sunburning and reduce desiccation by covering with a small perforated bag. Hotter inland climates may require a polyethylene sleeve inside the bag. In cool, more humid climates, painting with white latex may suffice.

Disease Control

***Phytophthora cinnamomi* root rot.** The most important avocado disease in California (and most of the avocado world), *Phytophthora cinnamomi* root rot has the nursery as its first line of defense. By law, a nursery that is shown to have introduced the disease to a commercial planting can be subject to severe monetary penalties. The root rot fungal organism, *Phytophthora cinnamomi*, must be rigorously excluded. Here is a list of wise precautions:

- Use a site free of *P. cinnamomi*; if you have any doubt, get a reliable laboratory to perform adequate soil sampling and testing.
- Choose a site without runoff from adjoining areas that are not under direct nursery control.
- Fence the nursery property as appropriate.
- Provide an entrance disinfectant dip for wheel traffic, activated daily with copper sulfate or sodium hypochlorite (chlorine bleach). Fortnightly activation is feasible with formaldehyde dip, but this chemical is now a suspected carcinogen.
- Provide entrance disinfectant for foot traffic, containing dry copper sulfate with flocculent. Liquid spray disinfectants (70 percent ethyl alcohol or a 1 percent sodium hypochlorite solution) can be used for shoes and for tools.
- Weekly, spray copper sulfate on the nursery approach roads and on all greenhouse benches, including the legs, plus floor areas. Keep water nozzles off the ground, and feet off the bench tops.
- Use high-pressure sprays to clean truck beds, and sprays containing sodium hypochlorite to disinfect trucks before loading trees.
- Fumigate all soils and soil amendments with methyl bromide or an equivalent at about 800 pounds per acre, or 2 pounds per 100 cubic feet.
- Fumigate the outdoor soil on which plant containers are placed with methyl bromide or an equivalent before new plant placement. This is especially important when the containers are open ended.
- Heat treat all seeds for 30 minutes in water at 120° to 122°F.



Fig. 20. A young grafted tree ready for commercial planting.

- Maintain constant vigilance against all possible sources of contamination.

The essence of the above practices are incorporated in a State of California certification program by which monitored nurseries can have their trees certified as grown with these sanitary precautions against root rot.

***Rhizoctonia* seed rot.** Though *Rhizoctonia* seed rot is not of concern in the orchard, in the nursery it can spread rapidly among closely planted seeds, killing as it goes. It can also kill young plants, or at least injure the roots. Follow these precautions:

- Drench all planting media with Terraclor.
- After the heat treatment, treat seeds with Benlate.
- Treat the graftwood with Benlate if you suspect contamination.
- Drench the large field pots with Terraclor before transplanting to them.

Sunblotch viroid. A systemic disease, sunblotch viroid causes yellow or sometimes pink depressed longitudinal streaks in stems, and often in fruits (where it results in culls). Symptomless carriers are known to show no hint of the disease, but to transmit it with full virulence. At times, sunblotch has caused serious orchard losses. A California Department of Agriculture program has eliminated most serious losses by taking graftwood and seeds from the isolated descendents of trees that were indexed for freedom from sunblotch. Such "registered" commercial trees are safer. When cutting unregistered graftwood, it is well to sterilize the pruners or other cutting tool with 15 percent chlorine bleach or a comparable disinfectant between trees. Remove any infected tree immediately—the viroid can spread rapidly in a grove from natural root graftage.

TOPWORKING

The usual reason for grafting a different top onto an existing grove tree is to obtain a more profitable variety, commonly with superior quantity or quality of fruit. Occasionally, growers may wish only to diversify their varietal holdings. Another possible reason for commercial topworking is that grafting a small cross-pollination branch onto an established tree may significantly benefit production of the major variety.

Many noncommercial growers with only a tree or two would benefit from topworking an inferior seedling or grafted variety to a better top. This conversion might change the tree to a standard commercial variety, or it might change the tree to a variety wanted as a dooryard tree because of some commercially undesirable trait—for example, the large fruit of Daily 11 and Nimlioh. Or, a grower might change the tree to match local conditions—for example, the great cold hardiness of Mexicola, which has a fruit too small and too large-seeded to be commercial. A dooryard tree may be grafted to two or more varieties. In addition to cross-pollination benefits, such a combination can provide fruit the year round. In the long run, pleasure-giving dooryard trees may well help the commercial avocado industry by encouraging

individual enthusiasts, who in turn introduce the fruit to their neighbors, friends, and perhaps visitors from regions where the avocado is still little known.

Topworking can make a good tree better-fruited, but it cannot be expected to make an unhealthy tree healthy. It won't cure root rot, citricola rot, sunblotch, or other diseases. If the tree is in borderline condition from neglect, rectify the care and reestablish a strong vigorous tree before topworking it.

Stump Grafting

For commercial topworking, the usual procedure has long been to cut the tree down and place scions into the cambial layer of the stump. The avocado is unusually well-suited to this drastic procedure. Its advantages over sucker grafting are

- Every tree can be readily grafted, whereas you can wait in vain for suckers, especially when the stump is cut low.
- Some suckers are weakly attached to trunk or root, and grafts onto such a sucker will be lost if the sucker detaches.
- The tree can be left intact with its fruit growing until right before grafting time, instead of being cut down the previous autumn to induce suckering. (You could autumn-girdle the trunk, but the resulting suckers might not be as vigorous, and the fruit might not develop as well.)
- Stump grafts usually grow more rapidly than sucker grafts.
- Because stump grafting uses larger scion wood than sucker grafting, the graftwood can be stored longer, and the timing of tree stumping is thus more flexible.
- Stump grafting has been in use much longer, with demonstrated long-range success.

Bark Graft

Compared with the notch graft, the bark graft requires less skill, requires less expensive tools, can be done more quickly and so more cheaply, and does not require such large wood, which is scarce in some of the newer varieties like Gwen and is becoming more scarce even in Hass as young plantings diminish. However, the bark graft does not anchor the scion as solidly on the stock as does the notch graft, and it requires separation of bark from wood. Bark grafting usually begins when the bark starts slipping and ends with the approach of summer heat, about mid-February through April. The weather affects these dates. Bark is said to *slip* when the cambium is actively dividing, and so, the tree is growing. At this time, the bark may be peeled easily and cleanly from the woody center of the trunk.

The stump. The grower commonly stumps the trees to be grafted ahead of time, cutting the trees down with a power saw. For trunks of 3 to 4 inches or less, a good hand pruning saw works fine. Sever the trunk at about 4 feet, first sawing about halfway through the trunk on the side toward which the tree will fall, and then making a second cut to remove a wood notch if there is concern as to where the tree will land. A third cut a little higher and on the opposite side of the trunk then fells the tree. To graft, make a smoothly horizontal cut at a height of 1 1/2 to 2 feet—high enough to provide a good base for the later staking and also to make the grafting



Fig. 21. Bark grafting: this metal tool is specially designed to force non-slipping bark.



Fig. 22. Alvin Lypps' s curved bark-thinning tool.

operation easier. The cut can be somewhat higher, especially if the bark higher up is significantly smoother or greener. Cutting the stump off at a slight angle from the horizontal will help to drain excess water and sap, but too much of an angle will make the grafts harder to wrap.

In sunny, hot weather when the grafting will be delayed more than a few minutes, protect the stump along its top cambial edge by replacing the trunk block produced by the final cut, or by covering the stump with a plastic-lined paper bag or with something like heavy white paper, perhaps held in place by a dab of tree seal at the cut middle. If, nevertheless, there is a little surface drying, you can spray with water before grafting. Also, protect the bark surfaces with whitewash or inexpensive white latex water-base paint (not oil-base, which is toxic to living plant tissue). Full-strength latex paint is safest, but dilution with an equal part of water is usually adequate, especially if you give the west side of the trunk a second coat. Paint brushes work well; spray equipment usually requires too much dilution.

The bark. Examine the circular cambial region for indications of earlier sunburn, freeze, or other damage, and do not insert scions at any such places. During the normal spring bark-grafting season, the bark on a freshly cut stump will generally separate (slip) with ease. This will last for a couple of days. Then the bark will gradually tighten, at a rate that may vary from tree to tree. Three weeks or more later, the bark should slip reasonably well again. Historically, bark grafting has required slipping bark. However, propagator Alvin Lypps has now designed a special tool (fig. 21) that forces bark separation for scion insertion. The tool necessarily involves some injury to the delicate cambial layer, but in expert hands the method has given success comparable to that with slipping bark. The tool permits bark grafting at any time after the tree is cut down. It also permits grafting earlier in the season, when trees are still dormant.

If the bark is heavy, as it usually is when the trunk reaches a diameter of 6 inches or so, it should be thinned to about 1/4 inch in each region of scion insertion. This makes it more flexible so it can lift away from the wood and fit better around the scion. Growers generally use a drawknife for the bark thinning, but with a little practice a propagator's pruning saw works fine. Lypps has designed a two-handed pruning saw (fig. 22) that is especially efficient because it curves to fit the trunk better.

Cut the bark vertically to about the length of the tapered cuts on the scion, usually with a heavy-bladed but sharp knife (fig. 23). Then open the bark flaps with the knife to receive the scion.

The scion. Stump size affects the number of scions. A 4-inch stump might have two scions; a 6-inch stump, three; a 12-inch stump, four. The number may also vary with scion cost and availability, and with factors likely to influence graft success, such as scion condition, tree condition, and grafting weather. Extra scions are desirable for three reasons: (1) insurance against individual graft failure, (2) insurance against later loss of the chosen successful graft, and (3) keeping the entire stump healthier by promoting added cambial growth. The best scion location is on the side facing the strongest winds, because at that position the wind pressure will brace the graft scion against the stump surface. The best scion usually gets that location.

Bark graft scions are about 3/8 to 3/4 inch in diameter, although both smaller and larger sizes have been successful. The uncut portion that projects above the stump end should be long enough to have two or three buds for survival insurance. It should be as short as possible to minimize desiccation—an extension of only about 3 inches is ideal.

Cut the scion with the desired taper for insertion and cambial contact where the graft union will occur. This cut is traditionally about 2 1/2 to 3 inches on the inward side and 1/2 inch on the bark side. Here again, Alvin Lypps has suggested an improvement. By making both cuts 3 to 5 inches long (figs. 24 and 25), the additional cambial contact permits a longer, stronger union that anchors the growing scion more solidly. This may be especially desirable with the new, more dwarf, precocious, and heavy-bearing varieties. For Lypps, the method of longer cuts is proving clearly superior. It does require a little more skill, and, obviously, the scions must be longer.

The ability to cut a good scion taper results from practice and superior techniques. Most beginners either have to shape the taper by whittling, producing an uneven surface, or else have the blade bite too deeply, producing a slightly concave surface. You can practice on any species of green wood. Learn to make a long, flat taper by means of slices that are single, slow, steady, and smooth. These together promote expert knife control.

technique + practice ⇒ full cambial contact ⇒ SUCCESSFUL GRAFT

In most grafting, the lower, uniting end of the scion is cut into a wedge with opposite sides tapering. The small cleft graft is a classic example of a wedge taper (figs. 13 and 14); lengthwise (vertical) equal cuts on directly opposite sides of the scion. The larger cleft illustrates the side taper. It, too, is a wedge, but has an additional horizontal taper from one side to the other—that is, the two vertical cuts are not directly opposite. Some skilled grafters choose to cut a small notch at the top of the cut (fig. 24) to hang the scion more securely on the stump.

Scion placement. Usually, the scion is inserted at the top of the stump (fig. 25) in the vertical bark cut (fig. 23). There are two standard placements. One is to center the scion in the bark incision (fig. 26a), nearly half of it under each flap. You can side-taper the outer (bark) side of the scion wedge (fig. 26a, lower cross-section) to get a snugger graft fit. The other is to place the scion under just one cut flap (fig. 26b), so the scion is flush with the cut edge. Here also you can side-taper the wedge for a snugger fit, but now you make a single taper, from the flush edge to the covered scion edge (fig. 26b, cross-section).

Another technique that is useful when the bark is not slipping is to insert the scion between two vertical cuts. Make two parallel vertical incisions into the bark, as far apart as the scion is wide. Both edges of the scion will border on bark incisions (fig. 26c). Here, the scion is not side-tapered.

You can also graft part of the way down a taller stump or intact tree and use the upper foot or two of the stump as a stake for the scion. This technique has the advantages that it permits the tree to continue normal functioning, provides a solid brace to which to tie the developing graft, and provides shade if the graft is on the north side. This placement does make a smooth union of stock and scion more difficult to achieve. When the graft is well established, the stump is sawed off, angling downward from the union.

Graft protection. Bind the graft region with 3/4- or 1-inch, 6- or 8-mil tape, (fig. 27)—the larger the trunk, the heavier the tape. Start at the top of the stump, solidly anchoring the scions, and work spirally downward. Overlap enough to be certain of a good seal and maintain tension to keep the wrapping tight. The wrapping can end just below the bottom of the cut surfaces with a tight half hitch knot (the end pulled under the last wrap). Often, the grafter spirals the tape back up the stump, spacing more widely but maintaining tension, ends the binding with a couple of wraps at the crucial top edge, and ties it there. If there is the slightest possibility of



Fig. 23. Bark grafting: making the vertical cut through the bark.



Fig. 24. Cutting the flat wood-side taper (notch at upper end is optional).



Fig. 25. One scion has been inserted, and the second is being tapered on the bark side with a chisel—a knife could be used instead.

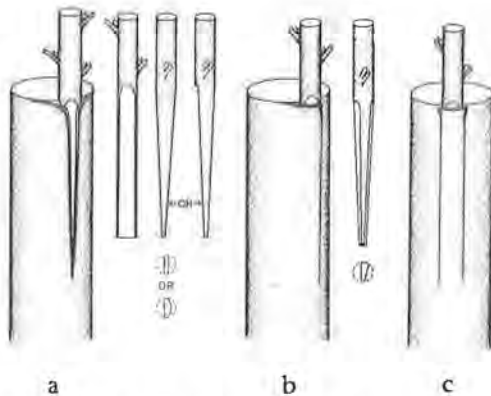


Fig. 26. Scion placement: middle of bark cut (a), side of cut (b), middle of two cuts (c).



Fig. 27. The wrapped scions are being cut back to two or three buds.



Fig. 28. A black asphalt emulsion seal coats the cut surfaces.

cut-surface exposure and desiccation, dab on sealant. Scions are sometimes nailed to larger stumps, but in the absence of wrapping, the ensuing callus can cause the scion edges to bulge out, creating a weaker union. Also, tape binding the top of the stump helps to keep the cambium and bark healthy. Tightly taping only the top edge and then fastening the vertically cut bark with 1- by 1 1/4-inch roofing staples has also worked well. Straddle the scion with three to five staples hammered in to seal the two bark edges, but not so far that they damage the scion.

All remaining cut surfaces of scion and stump must be sealed to prevent desiccation (fig. 28). Black asphalt emulsion works well. It is also viscous enough to plug the openings between wood and bark on either side of the scion. Sealant should not go down these gaps, as it would interfere with cambial union. If you use a more liquid sealant such as diluted asphalt, first apply it full strength to scion cuts and graft openings, and then apply the more liquid material from a separate container to the stump top.

The stump top needs protection against excessive desiccation. For decades, black asphalt emulsion was quite satisfactory. In recent years, for unknown reasons, serious *Poria* or similar trunk fungal rot has developed under the asphalt seal. Future substitutes may contain a disinfectant. In the meantime, asphalt diluted with water to the consistency of thick paint seems to strike a happy medium between deficient aeration that encourages trunk rot and excess aeration that causes trunk death from drying out.

When the sealant is dark colored, there is danger of scion death if the protective sunshade is lost. This can result from severe wind gusts, bird injury, especially from crows and ravens, or animal injury, especially from rodents. One way to guard against harm from sun exposure is to cover the black sealant with whitewash or white latex paint. You can apply the material with a brush, although that requires returning after the sealant surface has dried. A hand sprayer will apply the white coating successfully even to moist sealant. An alternative protection is heavy white paper attached to the fresh, sticky sealant on the stump, making certain that no black asphalt is exposed at the scion base. Paper evenly pressed on the wet asphalt will prevent the material from cracking when dry. For added safety, paint the scion white—at least its black tip and its west side, and its upper surface if it has any northward slope.

Painting everything white can provide adequate protection in cooler, more humid climates when you graft early in the year, if no heat wave or other problem arises. It is usually better to protect your grafting investment with a cover. This shields against the sun and provides some protection against frost, wind desiccation, and bird, animal, and other damage.

White butcher paper 18 to 24 inches wide makes a good cover, wrapped around the end of the stump at least twice, and projecting upward (fig. 29). Three or more layers of heavy paper will provide considerable rigidity, but it is best to support the wrap so it will not collapse onto the tender graft shoots because of rain or physical intrusion. Bamboo stakes work well, usually one beside each graft. Twine or tape outside the paper holds both it and the stakes in place. The top of the cylinder can be stapled shut or “sewn” with nails. Grafts in January and early February probably should have the cylinder completely closed to protect against frost. Later in the season, you should open at the top to prevent heat buildup, but not so much as to expose the grafts to direct sunshine. A cylinder that slants toward the north is obviously safer to open at the top than one that is perfectly vertical or that slants somewhat toward the south or southwest early in the year. Open a cooling air hole, perhaps 1 inch in diameter, by each scion at the cylinder base, and orient the flap to

prevent direct sunlight on the scion. Openings permit snail entry, so a little bait inside the cylinder will reduce risk to the succulent developing grafts.

Instead of butcher or other heavy paper, you can shade the grafts with paper bags of an appropriate size. Here also, reduce heat buildup with openings judiciously placed to prevent direct sun exposure. We are experimenting with cover materials that may be superior to paper in some situations.

Graft care. You must check covers regularly and replace them immediately if damaged. Crows and ravens are especially destructive to white paper, and the cover can also be harmed by rodents, wind, heavy rain, or mechanical injury. A few hours of full sun exposure can kill the scion, especially with black asphalt at its base.

As the new graft begins to grow, it gradually develops foliage that protects the scion and shades the stump top. You can therefore gradually and cautiously open the top of the cylinder to admit more light. As the bushy scion growth reaches the top of the cylinder, you can open the cylinder more fully, leaving its sides intact as needed to shade tender stems until the new plant has hardened off and developed a good head of foliage. Whenever black asphalt is exposed to sunlight, you must paint it white to prevent injury to the living plant tissue underneath.

The new graft will not be strongly attached to the stock for months, so you should stake it (fig. 30) at about the time that it grows out through the paper cylinder. In windy areas, two stakes per selected scion may be desirable. Pine or redwood stakes are satisfactory, 4 to 6 feet long, without large knots, and at least 2 by 2 inches square, and preferably 2 inches by 4. Grape stakes and lodgepole pine stems treated against rot are excellent because of their large size and grain-contour strength. Place the stake on the windward side of the scion and 3 to 4 inches away—close enough for snug support but not so close as to interfere with the graft trunk as it develops over the next few years. Nail the stake to the stump over as long a portion as you can. Use ungalvanized nails about 4 inches long, about three per stake. Stagger the nails to minimize stake splitting. Duplex (double-headed) nails are easy to remove when stakes are no longer needed.

The binding material should be strong enough to take the force of wind gusts and durable enough to last at least 2 years. It should be broad enough (1 or 2 inches) not to cut into the graft stem and firm enough not to become narrow by rolling up. Various materials work well, including strong cloth, nylon webbing, heavy-mil grafting tape, and other synthetic tapes.

The first tie-brace as the young graft emerges must be loose enough not to cut into the tender stem and yet firm enough to give support. It is best attached between two side branches to keep it from sliding down or slipping off the flexible top. The point of tie-stake attachment can be maintained by an extra half hitch before the final tie, or by a large-headed nail in the back of the stake.

As the graft grows, further ties will be necessary. The graft union will become stronger, but the plant will also become larger and more top heavy. A large bird alighting or a gust of wind—especially if accompanied by the added weight of rain—can mean disaster for the best of grafts with a single tie. Attach additional ties just above a side branch. Because the plant trunk is now more mature, the ties can be firmer, and you can probably retie the first one and move it upward for greater efficiency. However, ties may need loosening after a month or two of vigorous growth, to prevent constriction. Three well-separated ties provide good bracing support for grafts of good size (5 or 6 feet) by the end of the first growing season. Check and tighten each tie if necessary before the winter season or anticipated strong winds. The following spring, loosen all ties for unrestricted growth. Unless the stock trunk is small and securely joined to the enlarging graft, re-tighten the ties



Fig. 29. The butcher paper cover has a vent hole and is supported by two bamboo stakes.



Fig. 30. A staked tree 6 months after grafting.



Fig. 31. Two healthy grafts—all stems except one should have been tipped by now.



Fig. 32. The selected graft is pruned to one stem (which is sparse from excessive crowding), and the insurance graft is headed back.

for the second winter's wind. Thereafter, the well-developed graft should not need stake support.

When the graft you select to make the new tree develops two or more competing upright stems, usually with the beginning of weak crotches, remove all vigorous terminal buds except one. This should be done soon after growth begins and repeated as needed. Some grafts will need no tipping, and even two or three hand removals of growing tips will not require much time. If this job is neglected, you may have to prune more heavily later on, cutting back the extra trunks to side branches (figs. 31 and 32). However, the competition will have somewhat inhibited the selected stem, and the more foliage you remove, the more the tree is set back. After establishing a strong-crotched tree, perhaps by midsummer, you may face the opposite problem (chiefly with erect-growing varieties). That is, the tree may begin to be too slim and tall. The solution is now reversed: nip back the main growing tips. Again, repeat as needed.

Other procedures work reasonably well. One approach is to cut the 1- to 2-foot graft back to about 6 inches, producing a stockier graft that may not need staking, but you avoid staking at the cost of some tree setback and added risk from wind injury. Sometimes grafts are cut back 2 or 3 feet before the late fall period of strong Santa Ana winds in southern California, at least the first 2 years. Local wind conditions, windbreaks, varietal growth habit, and brittleness of branches will dictate whether this practice is appropriate. Such pruning may make grafts more vulnerable to the occasional winter freeze. Avocado tree pruning may, at times, be a necessary evil, but keep it to a minimum, especially when the young tree is becoming established. At UC Riverside, experience favors the removal of tip buds by hand.

Commonly, more than one scion will be successful per stump. The one you choose to become the tree is the most vigorous, or, in regions of severe Santa Ana wind, the one on the windward side. Because the best scion should be selected for this position, the ideal graft is both the strongest and the best placed. Nip the other successful grafts back as needed to reduce competition, but keep them all alive as insurance against later loss of the selected graft, and to keep the whole stump healthier.

The insurance grafts usually remain through the first winter, and often the second. Then you can remove them along with the top of the stump, which you saw off at a downward slope from the retained graft (fig. 33). This slope enables the graft to grow down over the stump top more readily and minimizes the risk of standing water that can lead to trunk rot.

Should such rot occur during the first summer, it is probably best to sacrifice the spare grafts in order to get rid of the rotted section. If completely removing the rot leaves a deep cavity, you can fill it with concrete. The exposed surfaces should be treated with a disinfectant such as Bordeaux mixture or fixed copper (Cu-OH_2 , etc.).

Occasionally, especially after a winter with exceptionally heavy precipitation, a stump will have continuously flowing sap. This can wash off the sealant and so expose the graft to desiccation. It can interfere with cambial union. And, the added moisture makes the stump more susceptible to internal *Poria* rot.

Avoid excess irrigation—water needs are obviously much less than in the pre-stumping condition. Cutting the stump at a slight incline from the horizontal helps sap and water to drain. Do not insert a scion at the lowest point of the stump cut. Check periodically for any drainage impediments, including callus growth. Watch such "bleeder" stumps for signs of rot. Immediately replace any lost sealant.

Keep all sucker growth from the stock root or stump nipped back to push the beginning graft growth and keep it from being shaded or crowded. But, to keep the plant healthy, leave as much foliage as possible. This could reduce the likelihood of zinc deficiency in the young grafted tree. Regular monitoring is necessary to maintain a good sucker balance.

Once the graft has grown out 1 or 2 feet, eliminate all present and future suckers. Cutting them back to stubs can leave dormant buds that will shoot out again, compounding your work, so totally remove each sucker. A hatchet works well for this. Use the blunt end to knock off young suckers and squash any recessed buds that a saw might miss. The sharp end is good for getting at basal buds that lurk between tree roots, and is another way to remove trunk suckers. Suckers that are missed will rapidly outgrow the graft and soon dominate the tree (fig. 34).

The avocado tree is unusually susceptible to injury from excess or deficient soil moisture. As soon as you cut the trees down, stop irrigations. Check the soil moisture regularly, using a tensiometer or soil tube. A mature tree usually will not need water until midsummer, or later. Young trees on light textured soils may require early summer irrigation. Irrigate only as the soil indicates need, maintaining the original pattern of distribution, and gradually increasing the frequency as the grafts develop. Tree basins that could collect rainwater are best opened for drainage, at least if there is significant clay in the soil. Branches retained when most of the tree is removed are known as nurse limbs, and these, by foliar transpiration, provide a hedge against excess soil moisture. (Nurse limbs also keep the tree healthier while the graft is uniting and starting growth, and they help to reduce excess sap exudate from "bleeder" stumps.)

The need for nutrition will be greatly reduced until the graft matures. Apply none the first year, then apply a little the second year, as you would for a smaller new tree of the same age. An exception might be prompt, full zinc applications on young grafts showing that deficiency.

Gopher and ground squirrel control is essential as always in the avocado grove, but certain problems become much more serious following topworking. Squirrels can chew on the protective covers and even on the scions. Dogs and other traffic can knock scions off. Deer prefer the tender new graft growth, and rabbits can be devastating as the scion grows out of its protective cover. Snails also prefer the young, succulent graft foliage, within striking distance of the ground, and can cause severe injury or even death. Crows and ravens have caused the death of many avocado grafts by knocking off graft covers or pecking them open to sun exposure, or by pecking out the graft buds. Even established grafts can partly or entirely break off when large birds alight on them.

Check with your local agricultural commissioner, farm advisor, or other authority for the newest and most effective means of combating these pests. Agricultural commissioners' offices usually have poisoned grains available, especially for control of ground squirrels and gophers. Dogs can keep rabbit damage to a minimum, particularly in conjunction with fencing. Dogs also discourage deer entrance. Both rabbits and deer are discouraged by repellents containing the chemical Thiram. Chemical controls are effective for snails, particularly metaldehyde.

Birds, chiefly crows, have recently become a serious concern on young stump grafts in some areas. The various repellents include sticky materials like Tanglefoot to discourage repeat landing, electronic distress and alarm calls specific to the pest species, carbide guns with irregular firing, moveable and changeable scarecrows, predator hawk likenesses underneath kites, replacement of covering paper with



Fig. 33. Eventually, a slant cut is made to promote stump healing. Most typically, the cut is made after the second year of growth (this graft was cut at one year).



Fig. 34. An unremoved sucker (arrow) will quickly outgrow the graft.



Fig. 35. Saw the stump at an angle.



Fig. 36. This sawed and chiseled cut is ready to receive the scion.

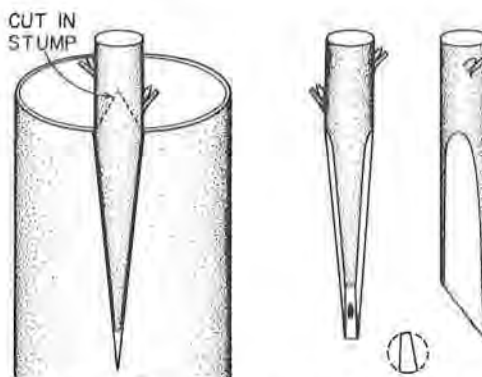


Fig. 37. Shaping and positioning for a notch (saw-kerf) graft.

other materials, field-active dogs, and protective bird netting on a frame (feasible on a small scale). The effectiveness of a repellent gradually diminishes and may be lost without the periodic rotation of these repellents, or the reinforcement of an occasional shooting; the crow is too intelligent a bird to be bluffed for long.

There must be clear understanding of respective graft care responsibilities among propagator, grove owner, and field worker. Divided responsibility is a good recipe for disaster. Usually, growers take care of their own grafts. Less experienced growers and field workers should have written instructions.

Notch ("Saw-kerf") Graft

Compared with the bark graft, the notch graft anchors the scion more solidly, does not need slipping bark, and because they are larger (fig. 7), its scions store longer—scions approaching 1 inch in diameter have remained graftable after a year in cold storage. However, because the notch requires more skill, more time, and larger wood, it has now been largely replaced by bark grafting. Most notch grafters need non-slipping bark wood because they usually have no scion-stock contact in the notch interiors, leading to excess pressure in the cambial regions and so slipping bark breaks away. The expert, in contrast, can get a snug fit of the entire scion-stock surface, and so extend the grafting season into spring—perhaps doubling the useful time period. Occasional slippage can be corrected by tacking or taping the bark down.

Stump the tree as described for the bark graft. Saw into the stump at an angle so that the cut extends about 2 inches inward and 3 inches down the side (fig. 35). A specially designed chisel is the best tool for widening the opening to match, but not exceed, the diameter of the scion to be inserted (fig. 36).

The scion will usually have a diameter of 1/2 to 1 inch. Larger scions are rarely available and smaller ones are more difficult to work with. Taper-cut the lower end on both sides for a length of about 2 1/2 inches. For notch grafting, the two cut surfaces must not be fully opposite—one strip of bark is considerably wider than the other (fig. 37, cross-section). Indeed, the narrower strip does not contribute to the graft union. The scion is then tapped into the stump V (fig. 38), thick edge outward. Because of its thinner bark, the scion's outer edge will be recessed in relation to the stump. Insert the scion at a slightly inward angle to ensure maximum cambial contact: at the top of the stump, the scion cambium should be just at the outer edge of the stump cambium; at the bottom of the scion, its cambium should be just at the inner edge of the stump cambium.

Some propagators believe that the stump cambial ring is likely to grow very slightly but significantly outward before graft union, and that the scion may not move with it; allowance for this by placing the scion further outward would be minimal. Scions should be straight, but a bit of curve is fine. Cut the tapers on the sides of the curve, with the wide bark strip on the convex side, and the slight curvature may actually make the scion easier to tap into the best placement.

As with the bark graft, the scion should project no more than about 3 inches above the stump to minimize desiccation. After inserting all scions, cover all cut surfaces with a sealant (figs. 39 and 40). This includes each scion tip, exposed scion cuts above the stump, the horizontal stump top, and vertical cuts below. No wrapping is necessary for the notch graft, but for sealing and covering, and all aspects of graft care, see the discussion of bark grafting.

Sucker Grafting

Compared with the preceding bark and notch stump grafting, the grafting of suckers requires less grafting skill, requires less expensive tools, permits the use of the more

plentiful small grafting wood, can be done more rapidly and therefore more cheaply, can be done over a much longer portion of the year, can be done lower, an advantage for erect varieties, gives much quicker complete healing of graft union to reduce breakage, and is useful as a fall-back technique when stump grafting fails and the trunk has become less suitable for grafting. However, it is a relatively new method, lacking long-term demonstration of commercial value.

Fallbrook Ag-Laboratory, Inc., has pioneered large-scale use of this topworking method and recommends the following procedures. Cut off the stump at 1 1/2 to 2 feet. This is shorter than for stump grafting, since the stump itself is not grafted, but high enough to encourage stump suckers. A somewhat higher cut could provide a sturdy tie support for sucker grafts, on the leeward side especially. The cutting is usually done after harvest, ideally with enough time to get the suckers started before winter. An alternative is to girdle no later than September to push suckers, leaving the tree to mature its fruit, but either the suckers or the fruit may fail to develop satisfactorily.

Immediately after cutting the old tree down, protect the stump against sunburn with whitewash or white latex paint, and against disease with Bordeaux mixture. You can do this by adding 4 pounds of Bordeaux to 1 gallon of white latex and then diluting with 50 percent water. Ag-Laboratory recommends against asphalt emulsion because of the greatly increased risk of stump rot. In regions that are hot in summer, diluted asphalt emulsion, perhaps in addition to Bordeaux or fixed copper, may be a good compromise between excess cambium desiccation and the rot hazard. Also, in hot regions, the white latex might work best at full strength.

As suckers begin to develop, remove all except three: two of them, preferably on opposite sides of the stump, will be grafted, and the third is left for insurance should one of the other grafts fail. Ag-Laboratory prefers suckers that grow low on the trunk. Suckers 2 or more feet tall are most easily grafted. First trim off all side branches to a height of about 1 foot (fig. 41), cutting to 1-inch stubs to avoid the risk of stem injury—the stubs will abscise cleanly on their own. Leave any stem leaves. Unless you plan to graft immediately, paint the exposed stem area white.

Graft near the top of the trimmed stem base in a smooth region free of side branches. The splice graft (fig. 42) is now the conventional technique for sucker grafting. It is essentially the same as the greenhouse splice graft. In the field, take even greater care to prevent desiccation by minimizing the exposure of cut surfaces. Outdoors, budding rubbers disintegrate too rapidly; use 1/2- to 1-inch 4- or 6-mil polyvinyl tape to seal the graft. A dab of asphalt emulsion seals the cut scion tip. Ag-Laboratory reports superior results using wrapping film instead of tape and asphalt.

Sucker stocks are commonly larger than the available scions. One solution is to match only one side of the splice cut (fig. 43), trimming excess stock to give a better taper. Ag-Laboratory suggests using a bent injector-razor blade attached to an art knife handle to scoop a rootstock cut equaling the scion width.

Stems and clear wrapping materials exposed to the sun must be carefully covered with white latex. The scion needs additional protection, as provided by an 8 1/2-x-11-inch sheet of cheap white paper rolled into a cylinder and fastened at its base, just below the scion, by two staples from a hand stapler, the cylinder top flaring somewhat to permit better scion development and better light (fig. 44). Avoid anything more than transient direct sun on the scion by angling the cylinder northward or closing the top with a staple. Butcher paper or other paper can also be used, as can various ties for the basal fastening.

A stake keeps the sucker from breaking out at its point of attachment to the old tree until it is firmly anchored. Stake when the scion has begun healthy growth, tying



Fig. 38. Tapping the scion into position.



Fig. 39. The two scions are in place, and are then sealed with black asphalt emulsion.



Fig. 40. The sealing is complete.



Fig. 41. These cut suckers are ready for grafting.



Fig. 42. Scion and stock cuts (the left splice graft is complete).

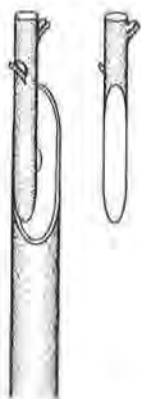


Fig. 43. A one-sided cambial match to join a small scion to a larger rootstock.

the stake to the sucker just under the graft. Add a second tie, to the graft, as soon as the stem grows out of the paper covering. (After both ties and before any constriction injury, cut the tape if the graft has been wrapped with polyvinyl instead of with automatically deteriorating wrapping material.) Make additional ties as needed with additional graft growth. Polyvinyl tape 3/4 to 1 inch wide and 8 mils thick makes a good tying material.

Downwind trunk suckers can be secured well to a taller stump, but root suckers that are somewhat removed from the stump are better off with individual stakes (fig. 45). A single 2-x-2-inch pointed wooden stake driven into the ground next to the sucker and extending at least 2 feet above the graft union can do the job. Two stakes are better, one on either side of the sucker, especially with unusual winds or other hazards. When each sucker has its own stake, the stakes can be tied together for support. You can use metal stakes about 3/8 inch in diameter, driven into the tree root if necessary. Maintaining white latex sun protection for the exposed stems is essential and may be needed into the second year, until scion growth provides adequate shade (fig. 46).

(For the important subjects of suckering, irrigation, fertilization, and pests, see the discussion under bark grafting.)

Framework and Miscellaneous Field Grafting

There are several ways to graft an established tree to one or more selected varieties without changing the basic framework of the tree. That is, you graft into the ends of a number of branches on each tree. With most fruit trees, frameworking is a way to change over from one variety to another, but the unusually rapid growth of the avocado tree ordinarily prevents this approach from being worthwhile. The commercial avocado industry uses this method primarily when working small tree portions into a second variety for cross-pollination. Even for that purpose, usage has not been great. However, evidence suggests that much more provision for cross-pollination could be commercially profitable.

Choose a vigorous upright stem with full sun exposure or one that can be tied upright after grafting. Or, cut back the desired part of the tree a year ahead of time to stimulate upright shoots. Depending on relative growth vigor, you may later need to cut back either the original tree or the topwork in order to maintain a balance. Minimize heavy pruning by routinely removing growing tips or by tying back branchlets.

Frameworking is sometimes used with dooryard trees. You can graft several varieties onto a single tree, for added interest and year-round fruit at optimum maturity. Even if you want only one variety, frameworking permits its establishment with minimum disruption to the tree's aesthetic or shading function. Where this is important, the stem-side grafting methods are obviously ideal: veneer and side-insertion grafting, and shield, patch, and chip budding. The splice and cleft, although requiring more top-removal, are more widely used.

Splice grafting. The technique for splice grafting is basically the same for frameworking as for greenhouse and sucker grafting. Follow the methods shown in those sections.

Cleft or split grafting. The method described for cleft grafting in the greenhouse can be used for framework grafting, but somewhat larger scions are preferable outdoors, up to 1/2 inch in diameter. The stock may be no larger than the scion, or as large as 2 inches or more in diameter. Stock should be vigorous and immature,

as shown by green bark, in order to split easily. Any sharp knife is fine for making the 2 1/2-inch cleft in a smaller stock. For larger stocks, a special cleft tool works better. For such large stocks, you can insert two wedge-tapered scions on opposite sides of the cut. In that case, each scion would be narrower toward the stock center to permit maximum cambial contact, as noted for the notch graft (fig. 47). The same is true of a single scion when it is smaller than the stock. Because the stocks are usually larger, the wrapping tape is commonly heavier (6 to 8 mils) outdoors. Shading can be provided by white paper cylinders, but a larger sucker graft is usually covered with a paper sack—like one type of notch graft protection, but on a small scale. Instead of waiting for the scion to grow out the sack end, you may gain advantage by removing the sack sooner and retying it to the stock to give shade only to the west and on top.

Veneer graft. As the name implies, veneer grafting involves removing a section of stock bark and replacing it with the scion (fig. 48). The stock is considerably larger than the scion, unlike the typical splice graft, and, unlike the splice or the cleft, veneer grafting does not require removal of the entire stock top. Thus, the scion is protectively shaded.

The scion is usually about 1/4 to 1/2 inch in diameter. Its lower end is tapered with opposite cuts forming a wedge at least 1 inch on one side and 2 inches on the other. Parallel vertical cuts about 3 inches long open the stock bark to the width of the scion. Join the cuts at the top with a horizontal cut. Then peel back the slipping bark for the full length of the vertical incision, cut off the top half of the flap, insert the scion wedge under the remaining half flap with the short cut toward the bark, and bind the graft with tape. Cover the cut end of the scion with asphalt. Asphalt should also be placed at the vulnerable angle where scion and stock diverge. Shaded by the upper stock, the scion may need no other protection than white latex.

With non-slipping bark, follow the same procedure, but cut the stock bark back instead of peeling it; a thin wood sliver may be under the flap. Various modifications can be made to the basic process. For example, you can completely remove the stock bark section, split the scion down the middle without tapering the end, and place it bark side out in the stock cut. It is then made flush with the inside cambium. As with other propagation procedures, your ingenuity may lead to other variations better suited to your situation or inclinations.

Remove the sucker growing tip to encourage scion development. If the scion does not begin vigorous growth within a reasonable time, cut the stock back severely or girdle it just above the graft. When you cut the stock back, it is well to leave enough stem above the graft to provide a sturdy graft brace. Eventually, you will remove the stock top completely with a saw cut angling downward from the top of the union.

The veneer graft has sometimes been used in the greenhouse or nursery growing ground on rootstocks that had failed the original grafting or that otherwise had become too large for the standard methods. As a rule of thumb in container propagation, use the small cleft on stocks up to 3/8 inch, the splice on stocks up to 5/8 inch, and the veneer on stocks up to 1 inch or so. With field trees, the veneer graft can be used on stocks much larger yet.

The veneer graft is a type of bark graft, but its usage differs greatly from that of the bark graft discussed earlier for stump grafting. The veneer graft is also a type of side graft. Its usage, unlike its procedure, is similar to that of the conventional side graft.

Side graft. Like the veneer graft, the side graft allows the stock top to be left intact. They differ in that the side graft stock cut goes into the wood (fig. 49).



Fig. 44. Paper cylinders (the right is complete).



Fig. 45. Sucker grafting: a 6-month-old graft (left) and two ungrafted suckers (right).



Fig. 46. A pair of trees 18 months after sucker grafting.

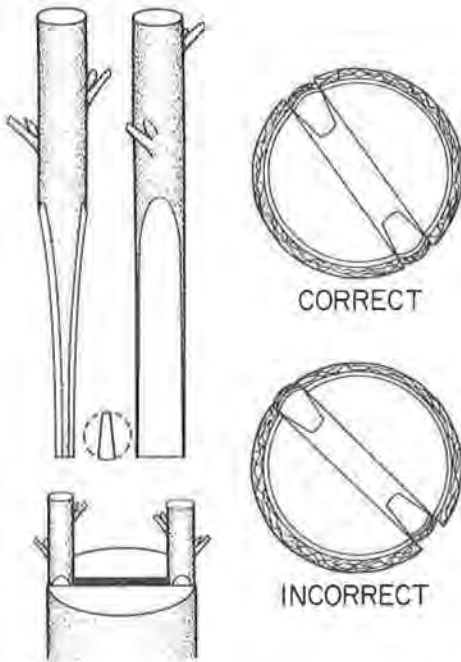


Fig. 47. Large cleft graft, showing the side-tapered scion wedge (top left, with cross-section), stock with two inserted scions (lower left), correct insertion with matching cambiums, and incorrect insertions with scion too far out or too far in.

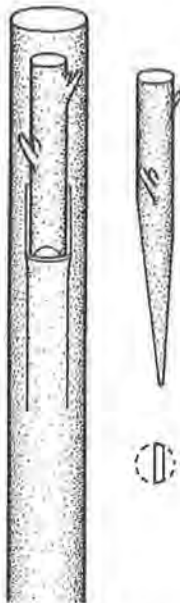


Fig. 48. Shaping and positioning for a veneer graft.

The scion diameter is about $3/8$ to $1/2$ inch. The stock can vary from about $1/2$ to a little over 1 inch. Give the scion the usual double-taper cuts, with one cut a little longer than the other. Then cut the stock well into the wood, but less than halfway across at 20° from the vertical. If it is small and rubbery, the stock may bend to open the cut sufficiently to receive the scion wedge. With less-flexible stocks, tap the scion in. A woodier stock may need a second notch cut to receive the scion. The length of the cuts will vary with scion and stock sizes. In any case, place the longer scion cut toward the stock center. When scion and stock are nearly the same size you can match cambiums at both bark edges; this may also be done with a larger stock by taking advantage of noncircular regions of the stem. Otherwise, match well on one side of the larger stock rather than let the scion cambiums at both edges fall fatally beyond the stock cambiums.

If the scion is solidly fastened in the stock, you need only seal all cut surfaces to complete the graft. Otherwise, tape-wrap the scion in place.

Shield or T-bud. Shield bud grafting is essentially the same for frameworking as for greenhouse grafting. Topworking stocks are usually much larger than nursery stocks, but should be young enough to have flexible bark. As always, outdoor grafting requires added vigilance to ensure that the wrapping is airtight.

Patch bud. You can think of the patch bud as a kind of "veneer bud." Remove a (usually square or rectangular) piece of bark from the stock and replace it with a same-sized patch containing a bud from the desired variety (fig. 50). Slipping stock bark works best. The method is simplest if stock and budstick have similar size and bark thickness, but the more concave patch of a considerably smaller scion will flatten suitably when wrapped, and the thicker bark of an older stock can be pared down around the bud patch to permit firm tying. A special rectangular tool with blades on all four sides is available for cutting out the two identical patches. Alternatively, you can use a double-bladed knife to make both pairs of horizontal cuts. Remove the bud patch with two single vertical cuts, join the stock cuts with a cut at one edge, peel back the bark to permit bud patch insertion, and make the second vertical stock cut to give a snug fit with the bud patch.

Chip bud. Another graft, the chip bud, has at least as good a claim to the term "veneer bud." It is indifferent to bark slippage and so can be done with good results at any time of year. For the base of the graft, cut well into the wood of the stock stem at about 45° downward. Start a second cut about 1 inch above the first, cutting first into the stock, and then smoothly turning the knife to cut straight down and meet the first cut. Remove the severed chip. Replace it with a bud shield of matching size (fig. 51), anchored at its lower end by the 45° stock cut. Wrap as usual.

PROPAGATION RESEARCH

Alert propagators are always seeking faster, cheaper, and more successful methods. These come from new technology, new applications of established technology, and new field insights. Some examples follow of innovations that now look promising, but are not sufficiently tested to merit general recommendation.

Wound Sealants

The established sealant material, asphalt emulsion (*bitumen*), has two serious weaknesses: its black color can heat the underlying live tissue to a lethal temperature on exposure to the sun, and avocado tree heart rot caused by *Poria* or other fungi is aggravated by the thick, tight asphalt seal. You can diminish the latter problem by diluting the emulsion to the consistency of a thick paint. However, more experimentation is needed, including determination of the ideal degrees of dilution under various circumstances.

Lighter-colored sealants are being tried. Although white would be the best color under hot conditions, a somewhat darker color might raise the temperature beneficially in the cool part of the year. Rubber latex sealants such as Tree Doc are fine on young bark, but have repeatedly caused injury when applied to the cambium layer of avocado cuts. Several other sealants have been rejected for the same reason. The search continues.

Wrapping Film

Avocado grafting may benefit significantly from the use of wrapping film. Fallbrook Ag-Laboratory is using the Parafilm brand to replace plastic tape in the splice grafting of suckers. Film has two major advantages: it is self-adhering when stretched, to make tying unnecessary, and it disintegrates under growth pressure, making later removal unnecessary (and preventing binding injury). Other promising uses include the replacement of asphalt as the scion tip sealant, and complete wrapping during budding for added protection against desiccation. Unlike grafting tape, Parafilm will readily stretch to accommodate bud growth. Like clear plastic tape, it must be painted white where exposed to the sun, unless it itself is opaque white.

Parafilm is reasonably priced when purchased in bulk and custom cut into 1-inch strips. It stretches to several times its length during the wrapping. Other, similar, materials are being tested.

Plastic-cloth Covers

The standard covering material, paper, is subject to water damage and bird pecking (especially from crows), and may not provide the best growth environment. Poly-spun polyester loose cloth, such as the Duon and Reemay brands used as vegetable row-crop covers, may prove better. The fibers are ordinarily impervious to both water and pecking, and their flexibility discourages bird landing. Tests of these materials have produced exceptionally well-developed scions. At least part of the reason may be the gentle light penetration from all sides.

The plastic cloths transmit about 70 to 90 percent of available light, varying with cloth weight. You can decrease the light for avocado grafts by added layers of wrapping, and heavier cloths may become available. The ideal percentage of light transmission has not yet been determined, but grafts have died when hot weather

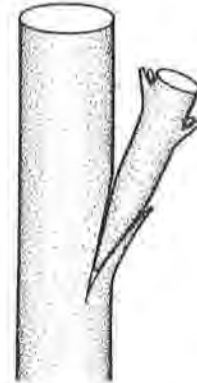


Fig. 49. Shaping and positioning for a side graft.

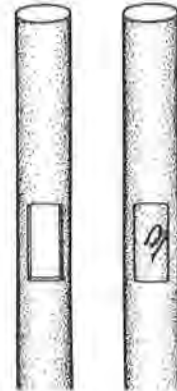


Fig. 50. Shaping and positioning for a patch bud graft.

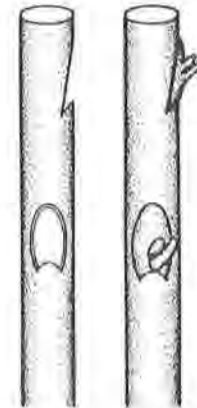


Fig. 51. Chip bud.

heated the black asphalt sealant, even under three or four layers of plastic cloth. The asphalt can be painted with white latex (more time-expensive), or a light-colored sealant may be developed, or heavier cloth used. More experimental work must be done. In the meantime, paper may be safer at both ends of the grafting season—frost hazard in winter and heat hazard in summer. Aluminum-like paper, reflective on one side, is used widely and with acclaim in Israel, and is reported to reduce internal heat substantially.

Metal Staking

Graft stakes can be difficult to anchor, particularly when the trunk for stump staking is at a considerable angle or is very rough, or when the ground for sucker staking is quite stony. One solution has been to use metal bars. A bar $\frac{3}{8}$ by 18 inches can be inserted into a $\frac{13}{32}$ - or $\frac{27}{64}$ -inch hole drilled 4 to 6 inches deep into the end of a 6-foot two-by-four stake. The bar is then driven into the ground to its free depth by hammering the top end of the stake. Its placement should be 3 to 4 inches from the graft, preferably on its windward side, and preferably touching the stump to which it is then fastened with a 4-inch nail. Modify the procedure according to the situation and materials at hand.

Regaining Juvenility

The degree of plant maturity, ranging from juvenile to adult, is referred to as *plant phase*, and is important in avocado production. The juvenile phase is incapable of flowering and therefore of fruiting, but it is the phase that initiates cambial activity and roots readily. If you graft a scion from a mature, fruiting tree onto a typical seedling stock, the scion growth will be less mature because of the juvenile character of the seedling. If you then graft wood grown out from this scion onto a young seedling, it will grow out still more juvenile. T. Murashige of the Botany and Plant Sciences Department, UC Riverside, has shown that five consecutive such graftings can transform a mature line to full juvenility, which can be maintained indefinitely. He and others are now working to apply this characteristic, plus tissue culture, to production of cheaper clonal rootstocks with root-rot resistance and other desirable stock traits.

Machine-cut Unions

Whenever a job becomes routine, ingenuity hunts for technology to relieve worker boredom and reduce labor costs. Thus, machines have been devised that make faster, smoother, and better-fitting graft cuts. Whether such a machine is worthwhile for a softwood tree like the avocado remains to be seen.

One grafting machine from New Zealand promises to save time while increasing the take percentage. It is new to the United States, but is growing in popularity in Europe and Australia. In southern California, it has had very limited avocado testing, but has worked well on macadamia wood. The machine is available in two forms, for saddle grafting or chip budding. Both are sufficiently portable for field use, and both can be solidly bench-mounted indoors. The cost, presently about \$300, makes it practical only for nurseries and large-scale growers with extensive propagation needs. Nevertheless, a grower who has smaller needs and a record of disappointing take percentages may find it to be the answer.

Research Summary

Progress is the most important product of avocado propagation research. The objective is to produce trees at a lower grafting cost, and therefore fruit at a lower production cost and a lower consumer cost. Change is often uncomfortable, and emotional inertia may combine with investment costs to slow its progress—the exciting future sometimes stumbles on the heels of the reluctant present. However, because of the highly competitive nature of avocado propagation, significant advances will generally be adopted soon after they become available.

Your own experiences, personal inclinations, and materials at hand may well lead to personal modification of propagation practice that is better for you. You may very well devise an improvement that is better for everybody.

GLOSSARY

Axillary bud. The single bud that forms in the junction of each leaf with the stem.

Bark. Broadly speaking, that part of the stem outside the cambium. *See* Wood.

Budding. A type of grafting that involves a single bud.

Budstick. A section of stem that provides either individual buds or a scion for grafting; also referred to as "budwood" or "graftwood."

Callus. Healing tissue that arises from the cambium at wounds.

Cambium. The invisibly thin layer of dividing cells between bark and wood (technically, between phloem and xylem, and giving rise to both). Successful grafting requires the union of the cambial layers of scion and stock.

Clone. Vegetative progeny of one plant. All clones of a single plant are presumed to be genetically identical.

Desiccation. Drying out; the deadly enemy of living cells, and therefore of successful grafting.

Etiolation. Elongated stems, pale from lack of chlorophyll, that result from growth in darkness. Etiolated avocado stems root more readily, so clonal rootstock propagators induce this condition.

Graft. Where the scion meets the rootstock; the completed operation of grafting; a grafted plant.

Pith. Soft, spongy tissue in the center of a plant stem.

Rootstock. Root-bearing plant or plant part to which the scion is attached in grafting. Often abbreviated to "stock."

Scion. The short stem portion, typically with three or four buds, for grafting onto the stock plant. The scion produces the desired fruiting variety (cultivar).

Slipping. Colloquial term for the condition in which bark separates readily from wood because of active cambial division.

Stock. *See* Rootstock.

Take. Informally, a successful graft.

Topworking. Grafting an established tree over to a new variety.

Wood. The part of the stem inside the cambium (technically, the xylem) that supports the stem and transports water and minerals upward; informally, scions, or stems with potential scions.

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