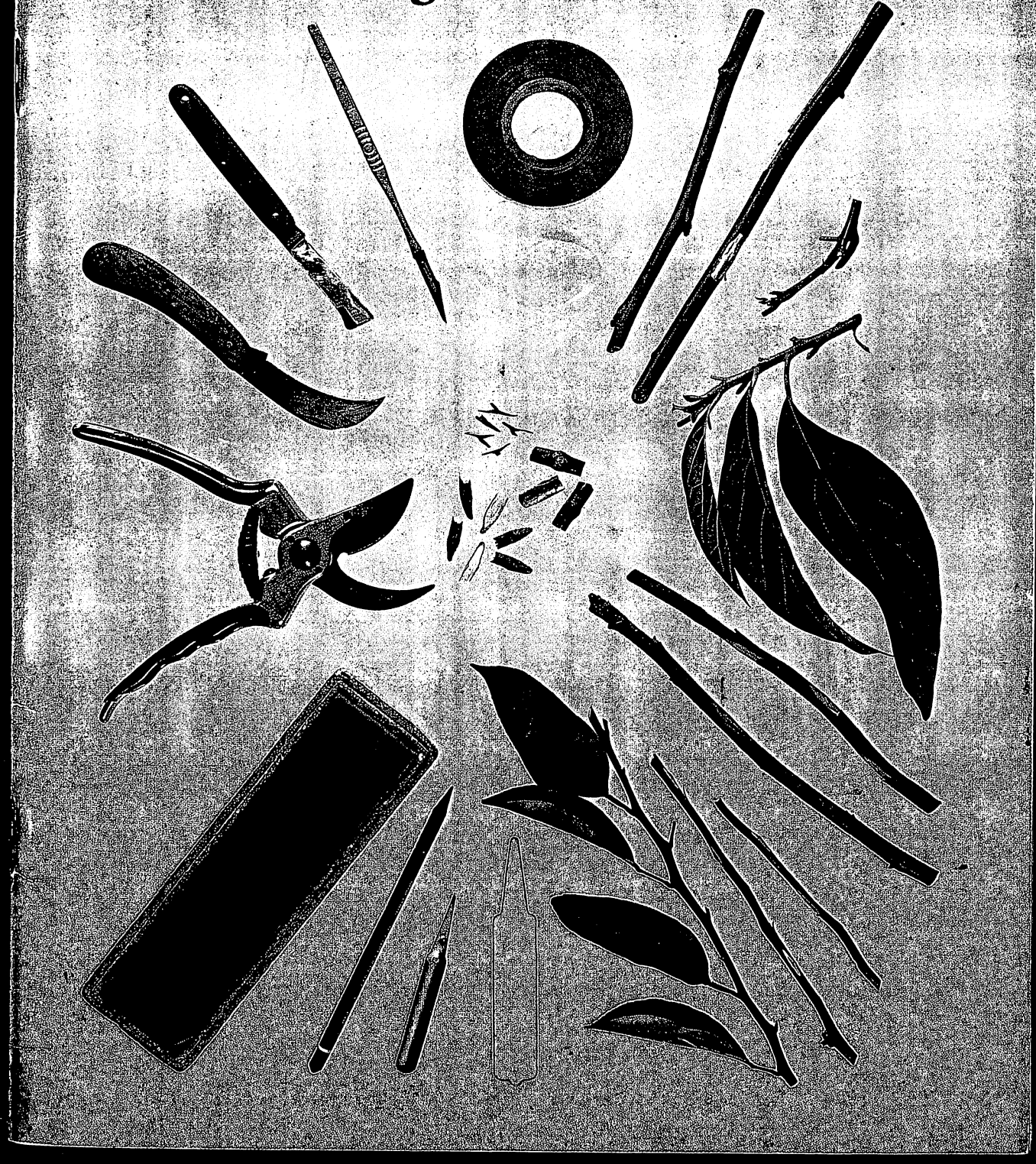
Practical Hints for Budding and Grafting Fruit and Nut Trees



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Practical Hints for Budding and Grafting Fruit and Nut Trees

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Front Cover

Tools of trade

Top centre
  P.V.C. grafting tape
Moving anticlockwise
  Scalpel—used for budding and grafting soft tissue
  Grafting knife
  Pruning knife
  Secateurs
  Sharpening stone
  Pencil
  Plant labels (x2)
  Citrus budwood (x3)
  Pistachio budwood (x2)
  Avocado graftwood (x2)
  Walnut budwood (x2)
Centre
  T-buds, chip buds and patch buds

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Introduction

Most fruit tree varieties which produce high yields of top quality fruit are propagated by budding or grafting selected scions onto selected rootstocks. On the other hand a limited number of fruit species such as figs (*Ficus carica*), olives (*Olea europa*), guavas, (*Psidium guajava*) and pomegranates (*Punica granatum*) can be readily propagated from cuttings and are commercially propagated in this way.

Selected scion varieties of fruit and nut species are preferred over unselected seedlings because of their higher yield, better fruit or nut quality and greater uniformity of their product. In many instances they are also better able to withstand pests and diseases. By contrast, unselected seedlings often produce low yields of low quality fruit which is generally inferior to, and often has little resemblence to, fruit produced by the parent tree. A further disadvantage of unselected seedlings is that they often take many years to produce their first fruit because they have a long juvenile stage.

For rootstocks, selected seedlings have proven advantages over self-rooted scion varieties with respect to tree anchorage, resistance or tolerance to soil-borne pests and diseases such as soil fungi and nematodes, tolerance to drought and/or waterlogging, and when combined with selected scions they have a predictable final tree size and produce high yields of high quality fruit.

The budding or grafting process is aimed at union between tissues of the scion with those of the rootstock followed by suppression of any subsequent growth from the rootstock so that the scion becomes the new aerial part of the plant. Success of the budding or grafting operation depends on having a rootstock in a suitable growing condition, suitable scion graftwood, a suitable technique for budding or grafting and suitable growing conditions. The timing of the operation and correct aftercare are also important ingredients for success.

Since the early 1970s CSIRO Division of Horticultural Research has established a wide range of tree fruit species in test sites throughout Australia. This booklet describes the techniques used for propagation of trees for these plots. Propagation of a selection of deciduous and evergreen species are described to illustrate particular examples of selection and storage of scionwood, and the timing and techniques of the budding or grafting operation and to suggest a time scale for each step of the procedure.

The techniques described may also be used by home garden enthusiasts to make best use of their available space by the use of multi-grafts. This technique combines several scion varieties on a single rootstock. Species which are classified in the same plant family such as all citrus species, all stonefruits or all pome fruit species may be grown on a single rootstock. Similarly different cultivars of a single species such as a range of peach varieties which in southern Australia mature their fruit from November to March may be grown on a single tree by budding different varieties to different branches.

The success of these techniques depends on the care taken in selecting scionwood for the following reasons. For some species virus free scionwood is not always available. In these instances and when virus free status cannot be maintained the incidence of virus or virus-like diseases can cause stunting and interfere with the balanced growth of the tree. Secondly, it is preferable to select scion varieties with similar vegetative vigour to avoid the necessity for continual pruning and associated loss of crop, in order to prevent the scions with least vigour from being overgrown.

Methods of Vegetative Propagation by Budding and Grafting

The techniques described may be classified as budding, when a single vegetative bud with only a small section of stem attached is transferred from the scion to the rootstock or as grafting, when a piece of scion stem bearing one or more vegetative buds is transferred.

The common aim of all techniques is to provide a good contact between the actively dividing (cambium) cells of the scion with those of the rootstock. Provided this is achieved and subsequent growing conditions are suitable, a high success rate may be achieved. If possible a humid position free of drying wind is preferred. Turgid plants such as those found in the early morning or soon after watering are also preferred. It is frequently an advantage to irrigate after budding or grafting to maintain the plant in a fully turgid condition.

For a successful union the aftercare of plants after budding or grafting is as essential as the operation itself. In this regard the following four points are of prime importance.

All lateral shoot growth of the rootstock must be removed or suppressed as soon as it appears to prevent the scion becoming overgrown.

Temperatures should be maintained between 15 and 30°C for good growth and callus formation. Temperatures above 30°C or below 10°C can slow down or prevent callus growth so that scions are killed or take an unnecessary long time to develop.

Sufficient water and nutrients should be supplied to maintain vigorous vegetative growth.

The budding or grafting tape should be removed or loosened before any growth restriction occurs.

Budding

Budding has the advantages over grafting that less scion wood is required for a given number of rootstocks and that the technique is generally less time consuming than grafting. Budding techniques commonly used include T-budding, chip-budding and patch-budding. With each technique several modifications are available to suit particular operators and conditions. With all techniques the rootstock is prepared first and then the scion so that a minimum of time elapses between cutting the scion bud and its insertion into the rootstock and final wrapping.

1. A T-bud is used only on actively growing rootstocks when the bark (phloem) can readily be separated from the wood (xylem). This state of suitability can readily be tested with a thumbnail or the point of a knife. If the bark cannot readily be separated from the wood, it is preferable to use a chip-bud or one of the grafting techniques.

The rootstock is prepared by first selecting a straight piece of stem in a suitable position. Rootstocks need to be well supplied with water and nutrients and to have been restricted to a single shoot by rubbing out any laterals which appear.

At the point of budding, the diameter of the rootstock is preferably about the same or slightly larger than that of the scion. A curved cut, convex side upwards, through the bark but not into the wood is made across the rootstock with the knife blade angled at 45° from the verticle. This is preferred over a straight horizontal cut because it helps provide a hold to loosen the bark after the next cut. The second cut, also just through the bark is made vertically about 3 cm long from the centre of the first cut and towards the base of the rootstock. The bark is then loosened from the wood in preparation for insertion of the bud. After loosening it is pressed back into place while the bud is being prepared in order to prevent desiccation of the thin-walled cells of any exposed cambium layer.

The most suitable scionwood is the middle third of vigorous shoots of current seasons growth. When it is collected all leaves are cut off but petiole stubs are retained. Budwood may be stored in sealed plastic bags at a constant low temperature between 0 and 5°C until used. If the budwood is to be stored for more than a few days it is desirable to seal the cut ends of the shoot with a low melting point wax or a water-based plastic paint.

The bud is cut from the selected scion budstick by cutting with a sharp knife from about 1 cm above and through under the bud to about 1 cm below the selected bud. Care should be taken to make a single clean cut which is as flat as possible. Removal of any xylem tissue from behind the bud is preferred by some operators but is not essential.

The bud is then quickly inserted under the prepared bark of the rootstock and eased gently into position so that all the cut edges are covered by bark (Plate 1). The petiole stub is used as a handle for this operation.

Budding tape is used to cover the opening, taking care not to press too firmly over the bud. This may be achieved by first securing the tape below the cut and then wrapping in a spiral fashion to the top of the cut and back again. Pressure is exerted over the cut edges but not over the bud itself. The bud may be fully covered or left with its tip exposed. If the bud is fully covered the tape should be loosened after about 10 days to prevent any restriction of bud development.

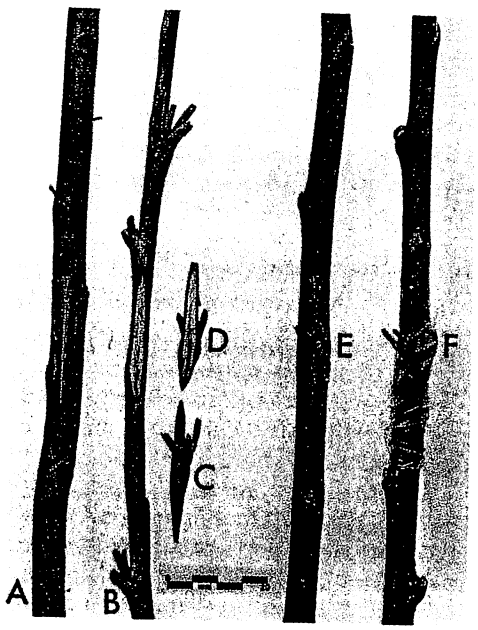


Plate 1

T-bud of peach.

A. Bark of rootstock prepared.
B. Bud cut from selected scion.
C. Outer view of bud.
D. Inner view of bud.
E. Bud inserted in rootstock.
F. Bud wrapped with P.V.C. budding tape.

At the time of budding the upper third of the rootstock shoot is pruned off and after the bud commences to grow the rootstock is further reduced. In windy situations it is convenient to leave a 10 cm stub on the rootstock above the bud so that the new shoot may be supported by a tie during its early growth. The stub may be completely pruned off in the following year.

The tape may be completely removed after about 3 months or earlier if necessary to prevent any restriction to growth.

A modification of this technique termed microbudding has been used for citrus. Young seedling rootstocks are used and budwood is selected from young shoots which are triangular in cross-section rather than round. The bud patch and T-cuts are made smaller than for normal T-budding. This technique has the advantage of using younger budwood which is often more readily available. However, it has a limited storage life and is best used fresh.

2. Chip bud. This technique is commonly used when the bark of the rootstock does not lift readily because of dormancy, low temperature or unsuitable growing conditions to enable a T-bud to be used. It may also be used as an alternative to T-budding because of the preference of the operator. As with T-budding it is preferable for the scionwood to be of similar or slightly smaller diameter than the rootstocks. For best results the scion should be of smaller or slightly smaller diameter than the rootstock.

The technique can be done very quickly because it involves only two knife cuts on both the rootstock and scion. The rootstock is first prepared as follows. The first cut is made in a suitable straight piece of stem with the knife blade horizontal and angled about 45° towards the base. The cut is made to about one third the diameter of the stem. A second cut is made starting from about 2 cm on the distal side of the first cut and continued to meet it. The chip is discarded (Plate 2A). Two similar cuts are made in the scion but with a bud in the middle of the chip (Plates 2B, C, D, E).

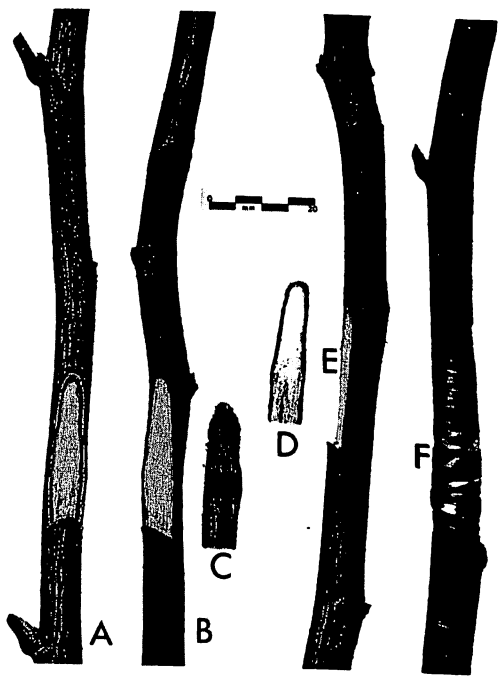


Plate 2

Chip bud of pistachio.

A. Rootstock prepared for chip bud.
B. & E. Bud cut from selected scion.
C. Chip bud outer view.
D. Chip bud inner view.
F. Chip bud inserted and wrapped.

The scion bud is then quickly transferred to the rootstock and wrapped tightly with budding tape. It has been found convenient to begin wrapping from the stem at the base of the chip bud. The tape is first secured around the stem and then wrapped in a spiral up and down so as not to cover the bud but to cover the cut edges. The tape is then secured at the base (Plate 2F).

As an alternative the bud may be completely covered by a loose wrap but it must then be exposed after two to three weeks when it begins to grow so that its growth is not restricted.

With species such as pistachio, which has strong apical dominance, a semi cincture made with a single knife cut above the bud has been found to improve bud burst by reducing the time taken for the bud to grow out.

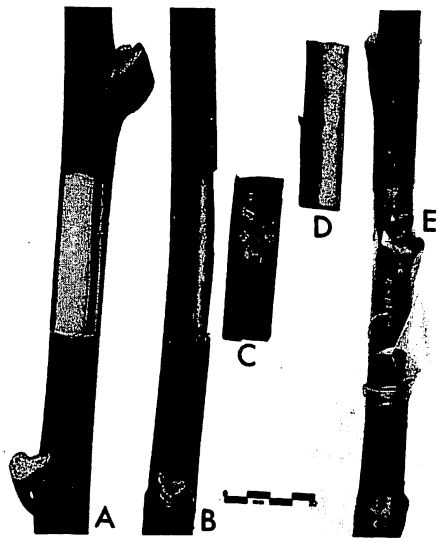
3. Patch bud. This technique is used for species which have thick bark which tends to split vertically such as walnut and cashew and for species with a latex sap such as sapodilla and jackfruit.

The technique consists of removing a rectangular patch of bark from a suitable rootstock and replacing it with a similar sized patch of bark carrying a single bud which is cut from the selected scion as illustrated in Plate 3.

Plate 3

Patch bud of walnut.

A. Rootstock prepared for patch bud.
B. Patch bud cut from selected scion.
C. Patch bud outer view.
D. Patch bud inner view.
E. Patch bud inserted and wrapped with P.V.C. budding tape.



A straight portion of rootstock is selected for budding and a plump vegetative bud is selected on a scion budstick preferably of similar diameter to the rootstock. Two parallel vertical cuts 1 to 2 cm apart and about 3 cm long are made through the bark of the rootstock and two parallel horizontal cuts are made to join them, so that a rectangle of bark may be removed. Care should be taken that the thin-walled cells of the exposed cambium are not damaged.

Next a similar sized patch is cut around the selected bud of the scion. This is peeled from the scion budstick, immediately inserted into the prepared stock and wrapped with budding tape. The wrapping should be pulled tightly enough to ensure a good contact between the cambium layer of the rootstock with that of the scion, to exclude air and to retain moisture but not so tightly over the eye of the bud that the latter becomes damaged. Should the bark of the rootstock be thicker than that of the scion, the epidermis must be pared down around the edges of the patch. This will ensure that the budding tape will exert pressure on the patch of the scion so as to exclude air and provide a good contact between the cambium cells of the rootstock and scion.

Modifications of this technique include ring budding and the circular patch bud. For ring budding, an annular strip of bark is removed from the stock and replaced by a similar sized strip of bark including a bud which is detached from the scion. In the circular patch technique a round or oval patch is cut with an instrument similar to a cork borer and the patch is replaced with a bud cut from the scion to a similar shape using the same or a very slightly smaller tool.

4. Vee budding. An experimental technique used on citrus seedlings is the Vee bud. This is used on young seedling rootstocks as an alternative to microbudding. Like microbudding it has the advantages of rapid callusing because the tissue is actively dividing and of the ready availability of young budwood which is triangular in cross section. The Vee budding technique has the added advantage that all leaves on the rootstocks are retained so that any growth checks are minimized. Disadvantages are that graftwood of a suitable size is often thorny and that young scionwood has a limited storage life.

The technique involves two cuts on the rootstock and scion as follows. The first cut is started from the leaf side of the bud and extends about 2 cm towards the base of the rootstock. The leaf is retained. The second cut commences above the bud and extends behind the bud and about 2 cm further towards the base of the rootstock to meet the first cut (Plate 4A). Two similar cuts are then made to remove a bud from the scion. The scion bud is then inserted in the rootstock and wrapped with strips of self adhesive rubber or narrow (0·6 cm) budding tape (Plate 4).

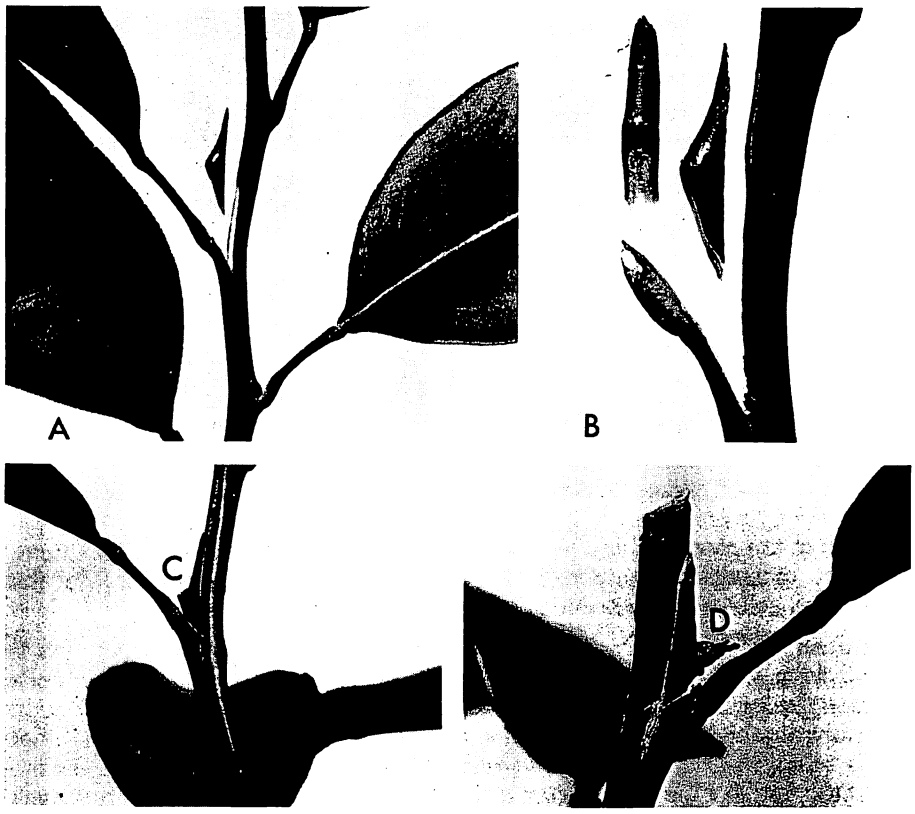


Plate 4

Vee budding of citrus A. Rootstock prepared. B. Bud cut from scion—side and top view. C. Bud inserted and ready for wrapping. D. Bud growth 8 weeks after budding.

Grafting

This is used in preference to budding when graftwood is freely available, when budding is unreliable because of uncontrolled abscission of buds, when the time is unsuitable for budding, when the rootstock is more mature than the scion or when its bark is too thick or to thin to be successfully budded.

The techniques have the following disadvantages over budding. They require more scion material, the cutting and matching of the cambium layers is generally more time consuming and also scionwood older than the current season is more difficult to cut and match. On the other hand the techniques may have the advantages of a higher success rate, a less specific time schedule, a greater tolerance for matching scions to rootstocks and a longer viable life of scionwood.

Scionwood used for grafting may be either dormant or green.

For deciduous fruits, graftwood is collected after the stage of deep dormancy and immediately before the first signs of growth in spring. It may be used at once or stored in sealed plastic bags at a constant low temperature of 5°C for use during the following six months. Graftwood is viable provided the cambium layer remains green and does not appear brown or black.

Graftwood of evergreen species is preferably collected immediately before the spring flush of growth but may also be collected immediately before subsequent growth flushes. Depending on its level of carbohydrate, graftwood will remain viable for up to four months if stored in sealed plastic bags at 5°C. When collected, all leaf blades are removed but the petiole bases are retained.

For green grafting of both deciduous and evergreen species, scionwood is collected from actively growing shoots. It is collected from the shoot on the proximal side of the bend when the shoot tip is pulled gently sidewards. It is prepared by removing the immature shoot tip and blades from one or two of the remaining terminal leaves. It is ready for use one to four weeks later when the petioles of the debladed leaves have abscissed but before the subtended buds burst. This technique is illustrated for the Annona in Plate 8.

Techniques for grafting include a terminal whip, whip and tongue, wedge graft, bark graft, side graft and approach graft.

These techniques are illustrated by line drawings in Plate 5 and for the approach graft in Plates 6 and 7.

Grafting Techniques

1. Whip or splice graft is used for rootstocks and scions of equal diameter and bark thickness. A long sloping cut is made across the rootstock and a similar long sloping cut is made across the scion (Plate 5 (1)) so that the cross sectioned areas of the cut surfaces of the rootstock and scion are similar. The cut surfaces are then held together and wrapped firmly with grafting tape. It is essential that the cut surfaces of the rootstock and scion are as nearly planar as possible to ensure that contact of their cambium is as close as possible. A tongue may be added but is not essential.

2. Wedge or cleft graft. The rootstock is cut off at the appropriate desired diameter and a single cut made down the centre (Plate 5 (2A)). The scion is cut to a narrow wedge (Plate 5 (2B)) and inserted into the cut in the rootstock (Plate 5 (2C)).

3. Whip and tongue graft for rootstocks and scions of equal diameter and bark thickness. Two cuts are made in the stock as shown in Plate 5 (3A). The first is a long sloping cut and the second commencing from the thin end about a third of the way to the top and sloping across the grain and towards the centre of the stock.

The scion is cut in a similar way (Plate 5 (3B)) and the two pieces are pushed together as shown in Plate 5 (3C).

The tongue is not essential but helps to hold the graft in position during tying and helps to ensure that the cambium layers of the rootstock and scion are in close contact. There may also be a response to wounding which assists the graft union.

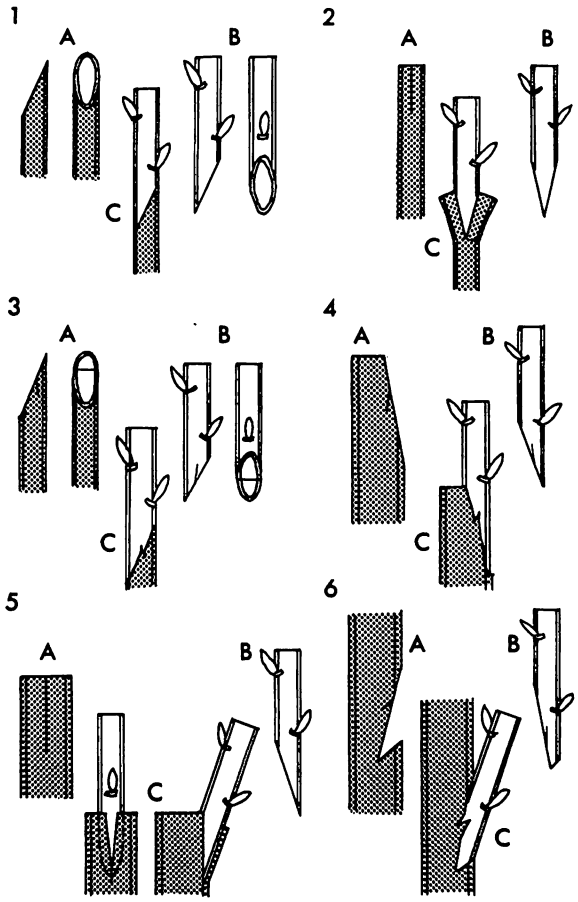


Plate 5

Line drawings of grafting techniques.

Note that the bark thickness is shown in each instance.

1. Whip or splice graft.
2. Wedge or cleft graft.
3. Whip and tongue graft.
4. Whip and tongue graft with the rootstock of greater diameter than that of the scion.
5. Bark graft with the rootstock of greater diameter than the scion.
6. Side graft with whip.

In each instance A rootstock preparation, B scion preparation and C the completed graft before wrapping.

4. For rootstocks larger than the scion graftwood, a whip graft or whip and tongue graft may be made on only one side of the rootstock. The size of the cuts on the rootstock and scions are adjusted to provide as much cambium contact as possible. A tongue may be added but is not essential.

5. An alternative technique for rootstocks larger than scion graftwood is a bark graft. The bark on the rootstock is cut vertically from the top of the pruned rootstock and loosened to allow the scion to be pushed down between the bark and the wood. The long sloping cut surface of the scion is inserted against the wood cambium of the rootstock (Plate 5 (5C)).

6. Another alternative technique used when the rootstock is thicker than the scion is a side graft. As with 1 and 4 a tongue may be added but is not essential.

For this graft a long sloping cut is made into the wood of the rootstock with a second cut made to meet its base (Plate 5 (6A)). A tongue may be added by a third cut towards the centre of the first cut. The scion is cut with a long sloping cut on one side, a shorter cut on the other and a tongue made towards the centre of the first cut (Plate 5 (6B)). The scion may then be pushed into place as shown in Plate 5 (6C).

7. Approach graft. The technique has the advantage of a large area of exposed cambium cells and many potential points of contact between the rootstock and the scion.

It may be used when the rootstock and scion are of unequal stem thickness and when a minimal growth check of the scion is desired.

The technique has been used during an experimental breeding program with avocados in which flowers were retained on the scion as shown in Plate 6 and produced over an extended period by collecting graftwood in August and storing it for up to three months before grafting.

Plate 6

Approach graft of avocado.

The base of the scion is kept under water to minimize grafting shock and to retain the inflorescences.

The procedure followed was to prepare the rootstock about a month before grafting by removing the shoot tip and all the buds in the axils of the leaves. This enabled carbohydrate to accumulate to a high level.

Scionwood comprising a 30 to 50 cm long shoot carrying terminal floral initials was collected with leaves intact immediately before the beginning of the spring growth flush. This scionwood may be stored in sealed plastic bags containing a few millilitres of water at 5°C for up to three months so that grafting may be delayed in order to alter the flowering time.

At the time of grafting, a strip of bark about 30 cm long and about two-thirds the width of the scion was cut from the rootstock. A matching strip was cut from the scion so that when the two cut surfaces were pressed together a maximum of cambium contact occurred. They were then pressed together and wrapped with grafting tape. The base of the scion was freshly cut under water and kept under water in order to minimize grafting shock and to prevent abscission of flower buds. Alternatively it may be buried in damp soil or completely wrapped with budding tape.

In order to prevent desiccation of leaves, the rootstock and scion were kept in a humid atmosphere by covering them with an inverted plastic bag. In common with all grafting techniques, the time taken between preparation of the scion and wrapping the completed graft to exclude air and to prevent desiccation should be kept as short as possible.

The grafting tape was removed after about 3 weeks from the terminal portion of the graft to enable unrestricted growth. The remaining tape was completely removed after 3 months.

A second use of an approach graft in which the scion diameter was very much larger than that of the rootstock is illustrated in Plate 7. In this instance the base of the scion was buried to prevent desiccation. As with the evergreen avocado a long (30 cm) portion of cambium of both the rootstock and scion was exposed, pressed together, and wrapped with budding tape. The rootstock thickened rapidly and after 3 months, when the photograph was taken, its diameter was about half that of the scion whereas initially it was less than a third.

Plate 7

Approach graft of jujube.

The rootstock (right) was very much thinner than the scion at the time of grafting. The photograph was taken 3 months after grafting.

Members of the Annonaceae

This family includes *Annona cherimola* (cherimoya), *A. squamosa* (sweetsop), *A. muricata* (soursop), *A. reticulata* (custard apple or bullocks heart) and *A. squamosa* × *A. cherimola* (Atemoya). For these species grafting is the preferred propagation technique. They may be grafted in spring with grey-green mature wood of the previous season's growth or alternatively with green wood collected from the current season's growth during spring, summer and autumn when the scion is in active growth. With both techniques, vigorously growing rootstocks are required but very young rootstocks may be used only with the latter technique.

Annona buds develop in hollow petioles so care must be taken to ensure that the buds are not damaged when collecting graftwood by retaining the petiole bases.

As shoots mature the bark colour changes from green to grey green to light brown. Grey green wood is preferred for grafting one-year old stocks as it is most suitable for grafting to rootstock shoots of similar age.

Green grafting using young green shoots of the current season's growth may be done on seedlings 3 to 6 months old and has the advantage of rapid budburst, which may occur about 3 weeks after grafting. Graftwood is selected from current

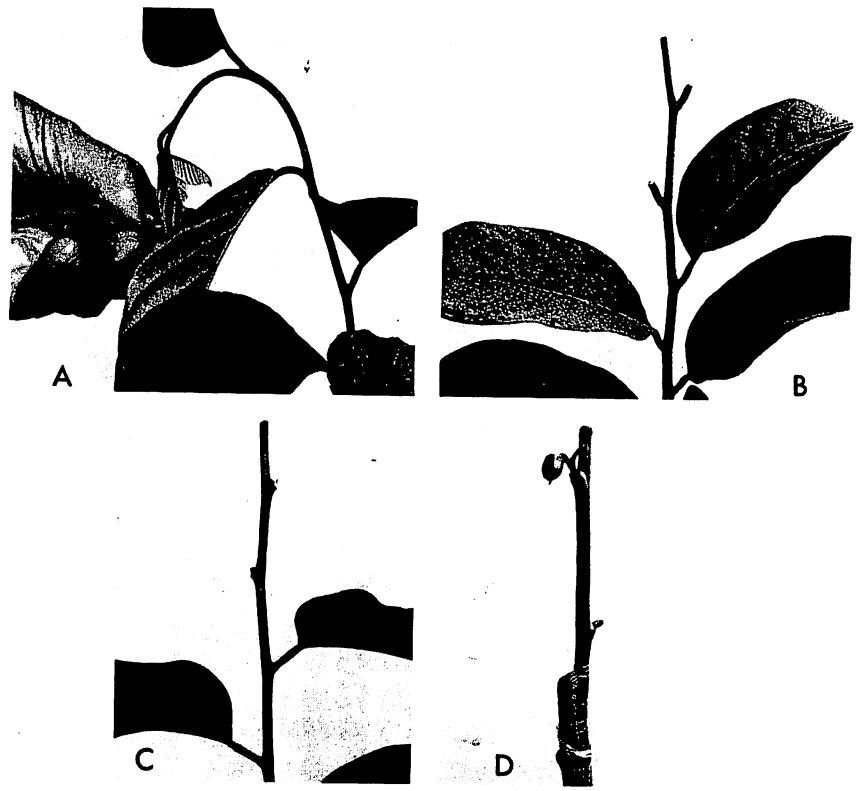


Plate 8

Green grafting of Annona.

A. Selection of scionwood. The portion of stem proximal to the bend is used.
B. Preparation of graftwood. Shoot tip and leaf blades of terminal leaves are removed.
C. When petioles absciss the graftwood is ready to use.
D. Scion growth commencing approximately 3 weeks after grafting by the bark graft technique.

season's growth taken from just below the bend of the shoot when the shoot tip is bent sideways (Plate 8A). The shoot tip and terminal two leaf blades are removed (Plate 8B) and the graftwood is used about 2 to 3 weeks later when the petioles have abscissed (Plate 8C). The graft is made to a seedling shoot at a similar position below the growing point or alternatively on seedlings of greater diameter using a bark graft (Plate 8D).

This green grafting technique has also been used for a range of other species including *Ziziphus jujuba* (jujube), *Diospyros kaki* (persimmon), *Euphoria longan* (longan) and *Casimiroa edulis* (casimiroa).

Avocado

Preferred graftwood is collected immediately before the spring growth flush. At this time, which in southern Australia is about the end of July, shoots contain their maximum levels of carbohydrate and the stems are stiff and woody. The terminal 5 cm of fully exposed shoots are selected, all their leaf blades are removed but about one centimetre of each petiole is retained (Plate 9A). Abscission layers are formed at the base of the petioles which absciss either during storage or when the graft commences to grow. Graftwood may be stored under refrigeration at 5°C in sealed plastic bags for use until about mid-December. Graftwood remains viable until the cambium layer which is green initially, begins to darken to brown or black.

Alternative sources of graftwood are terminal shoots collected just before subsequent growth flushes or the portion of the shoot adjacent to the latest growth flush. These have a ring of buds which were formed around the growing point of the previous flush when its shoot elongation slowed down and are termed knuckles (Plate 9B). Knuckles may be used at any time. However if large numbers are required, an excessive number of leaves must be removed from the scion source trees when they are collected.

Plate 9

Avocado shoot selected for graftwood. Pruning cuts are indicated.

A. Terminal scionwood. B. Knuckle. The ring of buds which was the tip of the previous growth flush is indicated by the arrow C.

The most suitable time for grafting is when maximum temperatures reach 20 to 25°C and when the diameter of the rootstock above at least 6 basal leaves is similar to that of the scionwood. The section of rootstock stem just below the bend of the shoot when its tip is bent sideways and which has a solid core without any differentiated pith is preferred for grafting (Plate 10). If grafting is attempted on a more mature section of the rootstock greater difficulty is experienced in obtaining a good match of the cambium cells of the rootstock and scion because of the central core of pith in the rootstock.
Grafting may be done by the whip, whip and tongue (Plate 11), wedge, bark graft or side graft technique.

Plate 10

Avocado seedling suitable for grafting.

Tip bent over to indicate the most suitable grafting point A (arrowed).

Oblique sections of avocado stem from the most suitable grafting point (A) and a more mature portion (B). Note the central pith in the section from (B).

Plate 11

A whip and tongue graft of avocado ready for wrapping.

The graft union is wrapped tightly with budding tape to exclude air and retain moisture and the exposed terminal maintained in a draught free humid atmosphere. This may be achieved by completely wrapping the scion with budding tape or by enclosing it in a small inverted plastic bag in which the uppermost two leaves of the rootstock or part of them are inserted.

When grafting is performed in the open, a paper bag and some shading are required with this technique to prevent the temperature inside the inverted plastic bag from becoming excessive.

Depending on growing conditions and the vigour of the rootstock, the graft will commence growth after two to six weeks. The grafting tape should be removed after two to three months to prevent restriction of the scion growth.

If the graft is exposed to strong winds it must be supported for at least its first growing season to prevent it from being blown out.

An experimental technique for grafting small avocado shoots produced from embryos grown in tissue culture has been developed as part of the avocado breeding program for avocados undertaken by CSIRO Division of Horticultural Research.

Embryos at least 6 weeks old which were extracted from abscissed fruits grown from hand-pollinated flowers were successfully grown in tissue culture. When shoots from these were about the length and width of a match they were transferred from liquid to agar medium and hardened off for about a month. They could then be successfully grafted to rootstocks using the following technique. Young vigorously growing rootstocks about 30 cm high were pruned to the desired part of the stem and all their axilliary buds were removed. The

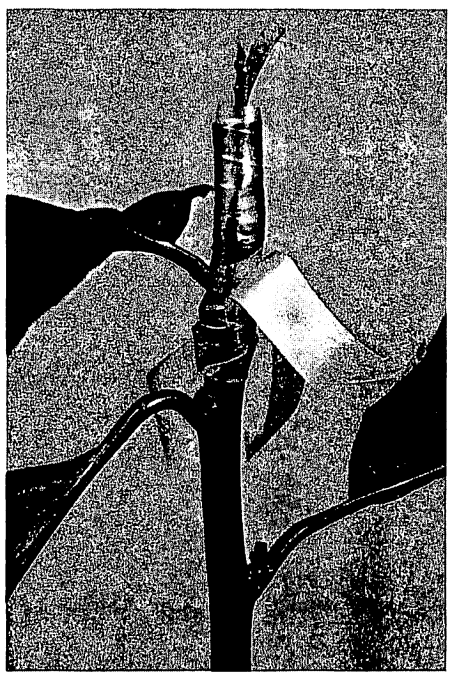


Plate 12

Avocado.

Tissue cultured embryo shoot bark grafted to 12-month old seedling.

6 Weeks after grafting.

pruned top of the rootstock stem was pared off with a sharp knife to aid subsequent callus formation. Two parallel vertical cuts through the bark at the top of the stock separated by the width of and about two thirds the length of the scion shoot, were then made and the bark between them was peeled back and cut off to leave a flap at the base.

The scion shoot was then removed from the tissue culture, washed free of agar medium and a long sloping cut was made through its base. The freshly cut surface was inserted under the prepared bark flap and held against the exposed cambium layer of the rootstock while it was wrapped with narrow (0·6 cm) budding tape (Plate 12).

Part of the uppermost two leaves of the rootstock were then inserted in an inverted plastic bag to provide a humid atmosphere and some shading for the graft. The bag was removed after three to four weeks when the graft commenced to grow.

Cashew

Under good growing conditions cashew may be propagated either by grafting using the splice, whip and tongue or bark grafting technique or by budding using the chip or patch budding technique. All methods are equally satisfactory.

Plate 13

Cashew graftwood prepared by removing leaf blades from a mature terminal.

After petioles have abscissed and buds have commenced to swell the graftwood is ready to use.

Whip and tongue graft of cashew on 12-month old seedling. 3 months after grafting.

The main ingredients for success are an actively growing rootstock well supplied with nutrients and water which is maintained at temperatures between 20°C minimum and 30°C maximum and graftwood of a suitable size and age which has been prepared one or two weeks beforehand. To prepare the graftwood first select a shoot with mature terminal leaves which has a stem diameter similar to that of the rootstock. The blades of the terminal two or three leaves are cut from the petioles which are retained. Two to three weeks later, by which time the petioles of the cut leaves have abscissed and the subtended buds have commenced to swell, the prepared shoot may be used for grafting by the whip or whip and tongue method (Plate 13). Using this technique the only freshly cut stem remains within the graft so that fungal attack and sap exudation is minimized. This is particularly important for cashew because freshly cut surfaces exude a sticky sap which provides an ideal medium for fungal growth.

For rootstocks, actively growing seedlings about three months old are preferred for grafting; but younger rootstocks may be successfully patch budded. The graft is most conveniently made by the whip and tongue method. For most rapid scion growth the graft is performed at the position on the rootstock proximal to where it bends if the tip is pulled gently sideways and preferably where the diameter of the stock and scion are similar. If the diameter of the rootstock is larger than that of the scion, a bark graft is preferred (Plate 14).

Desiccation of the graft may be prevented by enclosing it, together with the upper two leaves of the rootstock, in an inverted plastic bag. The opening at the base allows surplus condensed water to drain away. Condensation occurs only on the plastic bag and not on the graft.

Should any fungus develop on exposed cut surfaces or leaf scars it may be controlled by brushing or spraying with a general fungicide such as a mixture of benomyl and thiram.

The plastic bag may be removed after about one month when the graft commences to grow. The budding tape may be removed after about three months.

Young cashew seedlings less than two months old may be patch budded using the following technique.

Scion buds are prepared by removing the immature terminal shoot tip and leaf blades of several distal buds of shoots with a diameter approximately that of the seedlings. When the buds commence to swell and have developed to approximately 5 mm long with a distinct point, they are ready for budding.

The seedling rootstock is prepared by removing the terminal shoot tip above the initial rosette of leaves and any lateral or basal shoots which develop subsequently (Plate 15).

When the patch bud commences to grow, the leaf on the rootstock above it is also removed.

A patch surrounding the bud of approximately 6 mm wide and 20–25 mm long has been found adequate. Budding tape may be split into strips 6 mm wide to use with the small stems and buds.

The buds normally commence growth after about 4 weeks and the tape may be removed when the first leaves on the scion are mature (Plate 15).

This technique has the advantages of making maximum use of available scionwood because all buds can be used sequentially down the stem as they develop, of propagating a large number of plants in a limited space and of enabling budded trees to be field planted before they become pot bound.

Plate 14

Cashew bark graft completed.

High humidity is maintained around the graft by enveloping it with two leaves of the rootstock inserted in an inverted plastic bag.

Developing graft. 3 months after grafting.

Plate 15

Cashew seedling approximately 8 weeks after sowing. Prepared for patch budding by removing the shoot tip and lateral growth.

Cashew seedling, approximately 8 weeks after sowing, patch budded and protected from desiccation with a plastic bag.

Scion shoot development (arrowed) 4 weeks after patch budding.

Citrus

Because citrus is an evergreen genus, budwood may be collected at any time when a mature flush is present on the budwood source tree and when suitable rootstocks are available. The budwood may be stored under refrigeration at 5°C in a sealed plastic bag for up to 3 months. However a minimum temperature above 15°C and a daylength of 12 hours or more is required to maintain rootstocks in active growth.

Best results are achieved by T-budding between August and November or February and April. During early spring it may be difficult to obtain budwood with sufficient maturity.

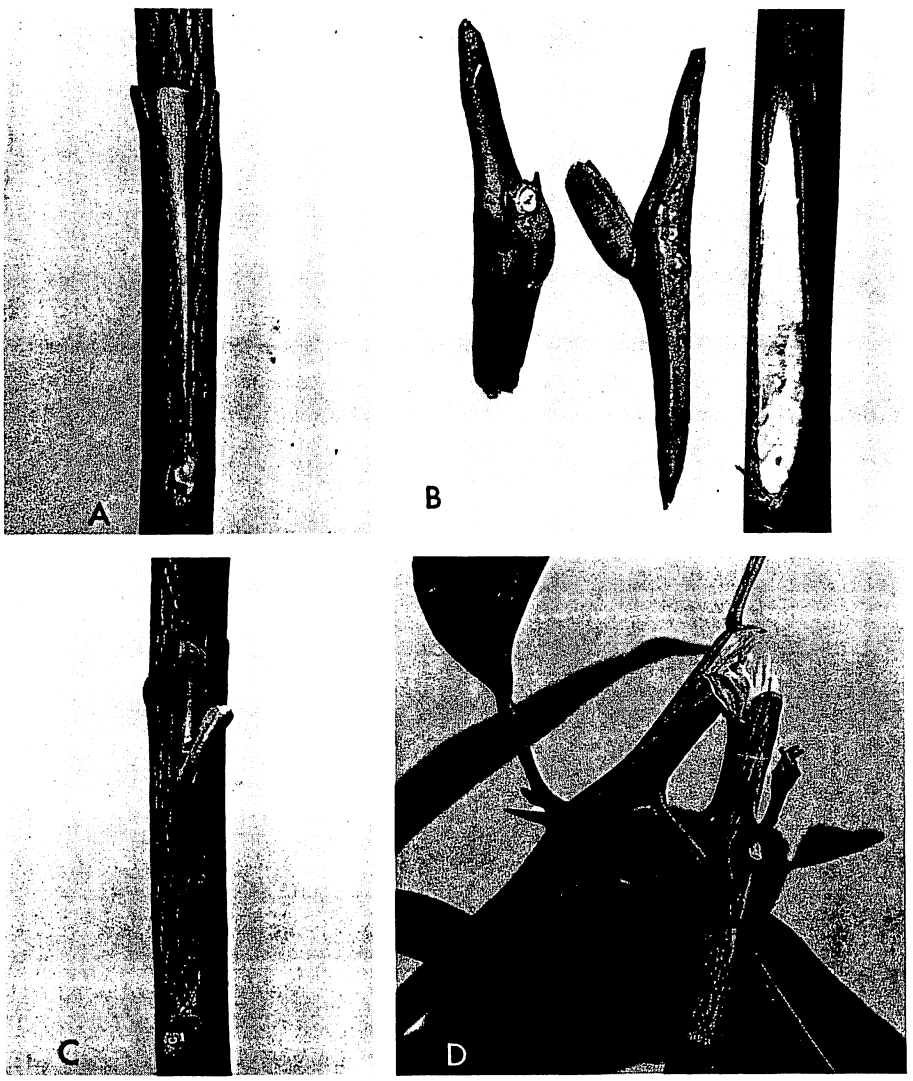


Plate 16

T-budding of citrus. A. Rootstock prepared. B. Bud cut from scion—top and side view. C. Bud prepared for wrapping. D. Bud growth 8 weeks after budding.

The most satisfactory budwood is the centre third of shoots with rounded rather than triangular wood carrying plump, well matured buds (Plate 16). When these are not available, mature buds on triangular stems may be used but for these a micro bud rather than a T-bud is preferred. Stages of T-budding citrus are illustrated in Plate 16.

Because of their thin shoots and absence of rounded stems other than on old wood, better results with mandarins and West Indian limes may be achieved by grafting. A short mature stem carrying one or two buds is used for such grafts either as a side graft or a terminal bark graft.

If immature buds are selected they may remain dormant after budding for several months and eventually burst during the following spring or autumn growth flush.

To encourage the bud to grow following budding, it is common practice to remove the terminal third of the rootstock at the time of budding. About three weeks later the rootstock above the bud is cut part way through and the terminal portion is bent over away from the bud. Photosynthesis from the bent over portion of the rootstock is sufficient to maintain the roots in a healthy state until enough scion leaves have developed sufficiently to commence exporting photosynthate.

On very young and soft tissue, microbuds may be inserted in T cuts in the stock or in Vee cuts in axils of leaves and held in place until the graft union is complete with self adhesive tape or with narrow (0·6 cm wide) budding tape. These techniques are exacting, require a very sharp knife or scalpel and a high level of dexterity but under good growing conditions will produce rapid results.

Macadamia

Graftwood is prepared by cincturing an exposed shoot or branch, and is collected when callus commences to form on the distal side of this cincture cut. It may also be collected in July just before the start of the spring flush of growth. Graftwood with a similar diameter to that of the rootstocks and with two whorls of buds is preferred.

Grafting is best performed as soon as possible after collecting the graftwood but the graftwood may be stored under refrigeration at 5°C for several weeks.

Rootstocks with stems of about pencil thickness and in active growth give best results. With larger rootstocks it is more difficult to obtain a good match with the graftwood because of the hardness of the wood. Some operators use a small plane to ensure that the stock and scion are each cut to a flat surface for ease of matching.

Good growing conditions and rootstocks in active growth are essential for a high success rate. A low level of phosphatic fertilizer and high nitrogenous and potassic fertilizers are recommended because, like all *Proteaceae*, macadamia is susceptible to a high level of phosphorus.

Mango

In common with avocado, greatest success has been obtained with mango by grafting rather than budding. This is because of abscission of buds after the budding process, even in instances when the bud shield remains alive and makes good union with the rootstock.

The graftwood is selected from mature, exposed shoots preferably with a diameter similar to that of the rootstock. It may be collected at the time when buds commence to swell immediately before the spring growth flush. At other times mature shoots are selected and the leaf blades are removed from the terminal whorl and the terminal 5 cm of the shoot (Plate 17A). After approximately two weeks the petioles of the debladed leaves will absciss and the subtending buds will commence to swell (Plate 17B). At this stage the graftwood is ready for use. Graftwood prepared in this way has the advantage of the absence of sticky sap which is exuded from freshly cut petioles. Mango graftwood remains viable in storage for only one or two weeks and is best used as soon as possible after it is collected.

The graft is made on young actively growing and well watered rootstocks preferably at the point where the diameter of the scion and rootstock is similar (Plate 17C). At least eight, and preferably more, mature leaves are retained on the rootstock to ensure that the roots remain healthy. If the diameter of the rootstock is greater than that of the scion a bark graft or side graft may be used.

An inverted plastic bag enclosing the two upper leaves of the rootstock or portion of them of sufficient size to extend above the graft has been used to maintain a high humidity and to prevent desiccation of the scion before the graft union is complete. When exposed to direct sun, it may be advantageous to cover the plastic bag with a paper bag to prevent overheating, but, in lightly shaded situations, the paper bag is unnecessary.

Plate 17

A. Mango graftwood prepared by removing leaf blades from a mature terminal shoot.

B. Graftwood is ready for use when petioles have abscissed and buds have commenced to swell.

C. Grafted mango.

Grafts normally begin to grow two to three weeks after grafting and at that stage the plastic bag may be removed. The budding tape should be removed after four to six weeks or when the new graft has produced some fully formed, mature leaves. A rapid and convenient method of removing the tape is to slit it down one side with a sharp knife.

Pistachio

Budwood may be collected either during the dormant season after leaf-fall or during January or February. Mature trees produce mainly flower buds which are about twice the size of vegetative buds (Plate 18). Each shoot of a mature tree normally has only a few vegetative ~~side~~ buds and a terminal one which are useful for budding and grafting. To produce a good supply of suitable budwood it is necessary to use either young trees before they crop or severely prune older trees to ensure that they remain vegetative. If the regrowth shoots are too thick for the rootstocks or if they begin to produce flower buds they may be pruned a second time in late November. For propagation, the buds selected should be plump and well developed and not immature or floral (Plate 18).

Plate 18

Pistachio shoots.

Left, vegetative buds suitable for budwood. Centre, female flower buds. Right, male flower buds. Note that the terminal bud is vegetative in each instance.

Dormant budwood may be stored under refrigation at 5°C in sealed plastic bags for about six months whereas fresh green budwood should be used as soon as possible after it is collected.

Under field conditions, considerable success has been achieved using the chip bud method in October with a maximum ambient temperature ranging between 15 and 25°C and minimum temperatures between 5 and 10°C. Rootstocks with stems about pencil thickness, in active growth and bearing some mature leaves are preferred. Under glasshouse conditions with temperatures ranging between 15 and 30°C, success also using the chip bud method has been achieved throughout the year on actively growing rootstocks provided the budwood is in a suitable condition.

Buds are wrapped to leave their tips exposed so that growth is not restricted. At the time of budding the upper third of the rootstock above the bud is pruned off but at least 10 basal leaves are retained to ensure that the root system remains healthy.

In February and early March field budding using a T-bud technique is preferred by some operators but a chip bud may also be used. For success with these techniques selection of plump buds is essential.

After budding, a semicincture with a single knife cut above the inserted bud has been used to offset the strong apical dominance of pistachio and has led to an improved bud take.

Shoots develop from the buds after about three weeks and if exposed to wind they should be tied to the rootstock. The budding tape should be cut on the side of the rootstock opposite to the bud only on the basal section about two months after budding. The upper section of the tape is left secured to restrict growth of the terminal part of the rootstock. The remaining part of the rootstock above the point of insertion of the bud is removed after nine to twelve months by a sloping cut about 15° from the horizontal and as close to the new shoot as possible.

Pistachio roots are particularly sensitive to, and are readily killed by exposure to dry air. Therefore, in order to avoid transplanting losses with this species it is essential to restrict exposure of roots to air or to desiccation to an absolute minimum.

Pome Fruits

Budwood is selected from exposed vegetative shoots preferably with a diameter similar to or smaller than that of the rootstock. It is collected either during the dormant season or in late spring or early autumn. Budwood collected in the dormant season may be stored for use on actively growing rootstocks in spring or may be used for grafting immediately before the rootstocks commence growth in spring. It may also be retained for budding in autumn but at this time fresh budwood is preferable. Selected buds should be fully mature and plump. The centre third of fully exposed annual shoots is preferred for budwood.

For grafting dormant graftwood on dormant rootstocks a whip, whip and tongue, cleft or side graft is used.

For budding in late spring or early autumn a T-bud or chip bud is preferred. In late spring either dormant budwood or if sufficiently mature, buds from new growth may be used.

Sapodilla

This species exudes a milky white latex whenever the bark is damaged so special techniques are necessary for its successful propagation.

Being evergreen, the species may be budded or grafted at any time provided the rootstock is actively growing, and suitable budwood or graftwood is available. A terminal whip and tongue graft, side graft or a patch budding technique are preferred.

For grafting, a mature terminal shoot is selected and the leaf blades are removed from the distal 5 cm. After approximately three weeks the petioles of the debladed leaves will have abscissed and leaf scars will have healed. The shoot may then be grafted in the usual way, without a problem of latex oozing, providing that long diagonal cuts are made through the bark of the scion plant five or ten minutes before the graftwood is collected. Similarly, possible problems with the rootstock are avoided by cutting through the bark of the stem or removing the shoot tip before making the graft in order to relieve the latex pressure.

As with other evergreens the graft may be kept in a humid atmosphere by enclosing it together with the upper two leaves of the rootstock in an inverted plastic bag. The bag may be removed after two to three weeks when the graft commences to grow.

For a patch bud the rootstock bark is cut diagonally as described for grafting. The bark of the scion stem is then cut to relieve the latex pressure, the patch around the bud is cut and the bud is pulled longitudinally from the stem without bending it. By this means the latex problem is avoided. After the bud is wrapped, a semicincture is made above the bud to further reduce latex contamination and to aid budbreak.

The rootstock stem is reduced by about one-third at the time of budding and it is further reduced when the bud commences to grow. The removal of leaves on the side of the rootstock carrying the bud can sometimes also assist the development of the scion.

Stone Fruits

Budwood may be collected while the tree is dormant or during the growing season. Buds selected should be pointed rather than rounded, the latter being flower buds. Where multiple buds are selected the central one should be pointed which indicates that it is vegetative. The outer two floral buds may then be rubbed out.

Budwood collected in the dormant season may be stored for several months but when collected during the growing season it should be used as soon as possible.

Budding is the preferred technique for propagation. The rootstock should be actively growing so that the bark lifts readily. A T-bud may be used in summer or autumn and the most suitable time ranges between December and March for different species as shown in Table 1.

Table 1. Preferred budding times for stone fruits

Species	Best budding time
Almond	Late December, January
Apricot	January
Plum	February
Nectarine	February
Peach	February, March

There is also a suitable time to bud in spring. At this time the budwood on budwood source trees is generally too immature for satisfactory budding so buds from stored dormant budwood is used.

At the time of budding it is common practice to remove the terminal third of the rootstock. The remainder of the rootstock may be used to support the developing scion but all suckers must be removed to prevent the scion being shaded out.

If the rootstock is wounded too deeply on some species a gum is exuded which prevents normal growth of the bud, so care is necessary to ensure that the T is cut only through the phloem.

Walnut

Graftwood should be collected during the dormant season prior to the commencement of bud swelling. It may be stored under refrigeration for up to six months for use after the rootstocks have produced their first fully developed leaves. Alternatively, graftwood may be collected in autumn and used while still fresh.

Graftwood should be collected only from vegetative shoots. On mature fruiting trees most of the buds produced are flower buds which are unsuitable for propagation. For this reason it is desirable to maintain source trees for budwood by pruning them severely in order to keep them in a vegetative state. Alternatively one or more branches of a mature tree may be pruned.

For successful propagation, rootstocks should be well watered, have a high level of nutrients and be actively growing. For a high success rate the maximum temperature should reach about 30°C with minimum temperatures between 15 and 20°C.

A whip and tongue or side graft, depending on the relative diameters of the rootstock and scion, are used after the rootstock has produced its first fully developed leaves in spring. Alternatively it may be patch budded either in spring or autumn. Patch budding is preferred to T-budding because walnut has a thick bark which tends to split longitudinally. For patch budding in spring, stored dormant wood may be used while for autumn budding mature leaves may be debladed a few weeks beforehand and the subtended buds used after the petioles absciss.

Ziziphus

There are two times during the year when ziziphus may be propagated. A high success rate has been achieved in early spring using dormant graftwood and also in late summer and autumn using prepared green graftwood.

Grafting is preferred to budding because this species has a very thin bark which rarely separates cleanly from the wood and which has a strong tendency to split longitudinally.

Graftwood should be collected from vigorous, vertical shoots because lateral growth tends to absciss during winter without retaining any viable buds. Dormant graftwood may be stored in a sealed plastic bag under refrigeration and used during August just before budburst of the rootstock. Green graftwood is best used fresh in late summer or autumn.

For green grafting, the scion shoot tip is removed together with the two terminal leaf blades from the proximal side of the point where the shoot bends if the tip is pulled gently sideways. When the petioles of the debladed leaves absciss, the shoot may be grafted to vigorously growing young seedlings. The actual graft is taped over and the tip of the graft piece is covered with an inverted plastic bag containing two leaves.

After about three weeks, during which time the buds burst, the plastic bag may be removed but the tape is best retained for four to six weeks.

The green grafting technique described above may also be used for a range of crops including casimiroa (*Casimiroa edulis*), persimmon (*Diospyros kaki*), longan (*Euphoria longan*), lychee (*Litchi chinensis*) and quandong (*Santalum acuminatum*).

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