Chapter 6: Fruit Trees

The sections above discuss everything you need to know to collect seeds, prepare your nurseries, raise seedlings, and plant them using agroforestry formations to begin protecting and revitalizing your Forest Garden site. In the second year, as your green walls and fertilizer trees are stabilizing and fertilizing your soils, it is time to start thinking about diversification. Following the Forest Garden Approach, we begin diversifying the perennials in Forest Gardens by planting fruit trees before moving on to timber trees and perennial shrubs, vine, and ground covers in year three.

Rearing Fruit Seedlings

There are endless species of fruit trees that could be planted in Forest Gardens, based on the needs and interests of the families who plant them. In TREES' Forest Garden projects, we tend to focus on those that meet market demand for families to earn income from them. As the scope of this manual is to offer general resources to guide trainers, we will focus on a handful of the more common species that families plant in their Forest Gardens.

Mango
Mangifera indica

Tree Description

Mangifera indica is a large evergreen tree to 20 m tall with a dark green, umbrella-shaped crown. Fruit an irregularly egg-shaped and slightly compressed fleshy drupe, 8-12 (max. 30) cm long, attached at the broadest end on a pendulous stalk. The skin smooth, greenish-yellow, sometimes tinged with red. The underlying yellow-orange flesh varies in quality from soft, sweet, juicy and fibre-free in high-quality selected (clonal) varieties to turpentine flavoured and fibrous in wild seedlings. The trees are drought tolerant but do not seem to suffer from occasional flooding. Mangoes are one of the most popular, widely-produced fruits in the world. However, production of local varieties with low yields and small fruit greatly reduces the profitability of mango cultivation. Specialized varieties require large amounts of start-up labor, and constant care for at least the first three years.

Bareroot Germination:

The best method to start mango seedlings is in a bareroot bed. Prior to sowing the seeds, double dig and amend the bed as we described above (see section on nursery beds). After preparing the bed, sow the seeds with 5 cm spacing between seeds, and 10 to 15 cm between rows, depending on the size of the seed. Then cover the seeds with a thin layer of soil.

Be Sure You Are Sowing Polyembryonic Mango Varieties

There are two varieties of mango seeds: monoembryonic and polyembryonic. Monoembryonic means it has one embryo inside the seed shell; Polyembryonic means there are multiple seeds inside each shell. However, polyembronic seeds generally take on the traits of the parent tree, where monoembryonic seeds do not. Whether you plan to graft your mango trees or not, it is best to select healthy fruits of polyembryonic varieties, grown near your Forest Garden. This will help to ensure they

There are a few reasons why it is beneficial to sow the seeds in a germination bed:

- To prevent seed rot, as water will drain more freely in the open soil of a bareroot bed
- The individual sprouts of polyembryonic seeds can be more easily thinned when dug up from the bed than when started in tree sacks

- Smaller or weaker seedlings can be left or replanted in the same bed (if pulled out during removal of stronger seedlings) for later use once the stronger seedlings have been moved.

Trenching Trees:
Once the healthiest seedlings from the bareroot nursery have been identified, they should be transferred to trenches. Trenching trees allows the trees to develop with more space and nutrients than are commonly available with tree sacks. Trenching also allows trees to establish a taproot that will be essential to drawing the nutrients and moisture required to survive grafting, and then allows easier removal of the root ball at outplanting. Typically, trees are trenched at the end of the rainy season. To trenchtrees:

- Dig a straight trench 50cm wide by 30cm deep.
- Carefully remove seedling clusters from the germination bed with a spade shovel, and gently separate the seedlings by hand. Select the strongest, most developed seedlings and transplant them into trenches
- Trim any kinked, rotten, or injured roots
- Return small or underdeveloped seedlings to the bed or discard them if you have the number of seedlings needed. If seedlings are diseased or pest-ridden, burn them. If they are deformed they can be composted.
- Transplant the healthy seedlings into the trenches, leaving 30cm spacing between seedlings.
- Remove all but a few of the leaves to cut down on evapotranspiration.

Trenching grants the following benefits:

- Water saving – Trenched trees require less water compared to trees out-planted in the field, this means less care while they mature to a graft-able age.
- Root care – Removing the bottom of the tree sack allows the taproot to grow without risk of damage or infections from water logging. The top part of the sack helps slow lateral roots to reduce transplanting stress.
- Grafting station – Tree trenches are the ideal place to graft, as they are protected and easily monitored.

Propagation Data

Propagation Method: From seed
Seed Collection: Seeds should come from matured fruits grown in your area. It should be free from insect damage, diseases or mechanical injuries. Avoid seeds coming from processing plants, since most of them are non-viable due to exposure from heat.
Seed Pretreatment: Dehusking or removal of the husk is recommended to facilitate fast germination. Be sure that dehusked seeds are plump and plant only those that are free from pest damage or physiological injuries. Healthy seeds should be sown with concave side down, 5 cm apart and 1 cm deep. This position prevents the development of crooked stem after germination.

Site Requirements

Preferred Soils: Mango does not have strict soil requirements, since the trees are deep-rooted and grow over a wide range of soil type and fertility levels. Planting trees in waterlogged areas should be avoided to prevent depletion from oxygen and infection due to soil-borne fungus.
Optimal Spacing: Generally at least 10 x 10m, but depends on variety

Tree Care

Pruning Period: Preferably pruning should be done during summer months after harvest. If done during the rainy season, the cut portions should be protected from fungal infection by application of fungicides, paint or coal tar.
Pruning Frequency: Pruning is done to remove undesirable and crowded branches which are of no use to the tree. This includes the removal of water sprouts, old, decaying and unproductive dried and overcrowded branches, infected and infested parts to discourage the presence and multiplication of insect pests and diseases. Pruning allowed maximum light penetration and air circulation in the canopy. This minimizes the build up of diseases inoculum and insect population particularly, mango leafhoppers.

Avocado

Persea americana

Tree Description

The Avocado is an evergreen tree reaching 10-20 meters in height. The small yellowish flowers are in clusters of thousands at the ends of new stem growth. Fruit shape ranges from pyramidal or pear-shaped to oval or spherical. The skin texture ranges from smooth to scaly with a color from dark green to violet. The flesh color varies from pale yellow to a clear green. Depending on the variety, fruit size may be 50g-2kg with up to half of that weight being the seed. Grafted trees begin producing fruit after 4-5 years, usually between May and December. Fruits mature 6-12months after flowering.

Propagation Data

Propagation Method: From seed
Seed Collection: Collect seeds still on the tree so as to lower the chances of the seeds picking up fungi
Seed Pretreatment: Soak seeds in hot water for 30 min as a treatment against the seed born fungal disease *Phytophthora cinnamoni*
Germination Rate: Allow seed to germinate by leaving it half submerged in a cup of water before being placed in a polypot, To ensure uniform germination
Time to Germination: Allow 4-6 weeks for germination
Time in Nursery: 15-18 months in the nursery
Grafting Method: Whip and tongue or T-budding are the most common
Age before fruiting: 4 to 5 years

Site Requirements

Preferred Soils: For best production, deep, fertile, well-drained soils, particularly sandy or alluvial loam soils and have a pH of neutral or slightly acid are suited for avocado.
Minimum Rainfall: Minimum annual rainfall requirement of 750 – 1,000 mm is recommended
Optimal Spacing: 8x8m spacing with 80x80x80cm hole

Tree Care

Pruning Period: Winter months
Pruning Frequency: Only those decayed or dead branches that hamper its growth should be pruned. Varieties which have a vertical growth can be pruned judiciously to encourage horizontal growth

Common Pests: Pests: Scales, thrips, and fruit flies are all pests of the trees; Root Rot (*Phytophthora cinnamomi,* fatal); Cercopsoriose
Irrigation Needs: In areas with distinct wet and dry seasons, water supply is very essential during dry months, especially during the first 2 or 3 years of the trees. Young trees are very sensitive to heat and water and should be irrigated regularly. Irrigate every two weeks.
IPM Methods: Root Rot: Avoid planting trees in soils that have poor drainage and avoid over watering; Cercopsoriose: Spray with benomyl at 10 day intervals during the rainy season and 28 day intervals during the dry season when fruit is on the tree.

Cashew

Anacardium occidentale

Tree Description

The Cashew is an evergreen tree that grows to a 10 to 12 meter height. It is easily recognizable by its spreading crown. Its leaves have rounded ends, clear veins, and are distinctively glossy. They leaves are spirally arranged and could be described as elliptical or obvate, 4 – 22 cm long and 2 – 15 cm broad, leathery in texture and a smooth margin. Cashew has a dominant taproot. The flowers are produced in a corymb of up to 26 cm long. They have five petals, and are initially pale green, eventually turning reddish.

Fruit Description

Fruit is a fleshy apple, typically 3-6 cm in size. Fruit color ranges from yellow to orange to red. The seed is attached to the bottom end of the fruit and hangs externally. The pulp is very juicy, but the skin is very fragile and extremely susceptible to consumption by insects, animals and birds alike. This makes it unsuitable for transport.

Propagation Data

Propagation Method: Cashew can be propagated by seeding in a nursery, direct seeding, and/or grafting.
Seed Pretreatment: You should remove the seeds and dry them in the sunlight. Pre-treat seeds in a 24 hour cold soak. Discard the floaters (They might germinate but won't necessarily produce good trees).
Germination Rate: Depends on the quality of seeds, but make sure to get rid of the floaters.
Time to Germination: Depends on how you plant the seed, but the seed should be planted like a desk phone, the bottom (bigger part) farther in the dirt and the top part showing a little for most rapid germination (approximately 5 days to one week with treated seeds).
Time in Nursery: Cashews should have 6 to 8 weeks in the nursery. Do not over water or the seeds will mold
Grafting Method: Whip and tongue grafting
Age before fruiting: 3 to 5 years

Site Requirements

A 20 x 20 x 20 cm transplant hole is sufficient. Be careful not to damage the taproot when transplanting. Do not wait too long to outplant seedlings as the danger of damaging the taproot increases. The planting distances for cashew varies depending on

the purpose the tree is supposed to serve. If planted in a field where crops will continue to be grown, 5 x 20 m space is generally recommended. For orchards, 12 x 12 m spacing is recommended. Cashews do well when direct seeded. Seed two per hole when the rains are regular. After a week, eliminate the weakest seedling.
Preferred Soils: Sandy well-drained soils are the best but cashew can tolerate a range of soils and climates.
Minimum Rainfall: 500 mm/yr
Optimal Spacing: 5m by 20m (recommended) in a field where crops will still be grown. 5m by 5m in orchard spacing

Tree Care

The cashew requires no special watering, cuvettes or pruning (in the early stages) in the field. Protect seedlings from animals. Seedlings and young trees should be weeded to protect them from dry season fires. It is good to inhibit fruit production until the third year, by cutting off the blossoms.
Pruning Period: You should start pruning three years after outplanting. For the period during the year, after harvesting, during the rainy season (July) is the best.
Pruning Frequency: Prune every year
Common Pests: Spiders very rarely
Irrigation Needs: None
IPM Methods: Weeding and pruning only

Citrus

Citrus spp.

Tree Description

Citrus trees are evergreen trees which will generally grow to heights of three to four meters depending on the variety. Budded or grafted citrus trees could be slightly smaller. Citrus roots reach downward to 1.5 meters. The secondary roots are between 0.15 and 0.8 meters depth. They have hard, dark colored evergreen leaves which contain oils. The fruit are all segmented. Some varieties do not contain seed. The seed may be mono- or polyembryonic.

Propagation Data

Un-grafted or un-budded citrus will flower and fruit as soon as five years after planting if in adequate conditions, whereas grafted and budded trees may flower as early as the year they are grafted.

Citrus is typically propagated in seed or germination beds. They should be composed of well-drained soils as to avoid rotting of the very sensitive citrus seeds. Water the beds often but lightly. In these beds, seeds should be sown 1 cm deep with 10-20 cm between rows. They can also be dispersed randomly in beds.

Trenching: Transplant into tree sacks when the citrus seedlings get close to being 15 cm tall. At this point a rigorous selection process should be used to eliminate any bad seedlings. Do not transplant unusually small or non-vigorous seedlings, seedlings with malformed roots, twisted, "j" rooted, or diseased seedlings. Only the best seedlings should be transplanted to the next step.

When transplanting trim the root hairs and the taproot down to 15 cm, this is to promote new growth. Rupert suggests shortening the seedling by 1/3 as well. Make a 15 - 20 cm hole in the center of the sack, plant the seedling into the hole, and press the soil around the roots trying to avoid any air pockets. Make sure the collar of the seedling is located in the same place relative to the soil surface.

Keep the sacks in the shade until the seedlings start to grow again. Make sure to weed the sacks regularly. When the rainy season is almost over dig the trench.

Propagation Method: Seeds and grafting
Seed Collection: Citrus seeds decompose quickly so only fresh seeds should be collected and used. Seeds should be dried in the shade never in the sun. When drying the seed do

not allow the seed to completely dry out but just dry out the surface for a couple of hours.
Seed Pretreatment: Mixing the dry seeds with ash may help against fungus attacks in the nursery. Store the seed in sealed plastic bags and if possible in a refrigerator making sure there is no humidity inside the bag to spoil the seeds. Seed in rows in the germination bed about 1 cm deep with 20 cm between rows. Sow seeds in the rows with 1 cm between seeds.
Germination Rate: 70%
Time to Germination: 15-30 days
Time in Nursery: One year
Grafting Method: Scions and budding
Age before fruiting: 5 years for rootsocks and as early as the first year for grafted tree

Site Requirements

The transplant hole for citrus should be 80 x 80 x 80 cm. Although citrus can be outplanted anytime of the year, transplanting in the dry season if water is not an issue, so the seedling can get established before the upcoming rainy season.

Preferred Soils: The soil needs to be well-drained. Adult trees need lots of direct sunlight to flower and fruit
Minimum Rainfall: more than 1200 mm rainfall per year
Optimal Spacing: 8 X 8

Tree Care

Citrus are very spindly and tend to branch from the base of the tree. In order to raise productive trees, pruning is a must. A citrus tree which is well pruned could be kept the size of a bush and even raised in pots without hampering its ability to produce.

Irrigation: Citrus trees will need to be irrigated for their first 3 years. In the drier areas and places with a deep water table irrigation may be needed throughout the life of the tree. Irrigation for most adult citrus trees is 20 liters 3 times a week. Once the trees are established and producing fruit, irrigation may no longer be needed but watering 2 -3 months before the rainy season can urge early blooming. If irrigated some varieties, notably the Japanese orange, will fruit all year round.

Pruning: Citrus species tend to require a lot of pruning. Most pruning should be done right after the harvest. Citrus fruit only form on new stem growth so branch ends should be pruned to urge new growth. Since it is very important for branches with fruit to have adequate sunlight, each year branches should be thinned and those "inside" the crown removed altogether to increase sunlight penetration. Other experts suggest only pruning any suckers originating from below the graft or bud site, any branches below 80 cm, and all dead branches.

Pruning Period: Citrus species require a lot of pruning. Most pruning should be done right after the harvest.

Pruning Frequency: Since it is very important for branches with fruit to have adequate sunlight, each year branches should be thinned and those "inside" the crown removed altogether to increase sunlight penetration.
Irrigation Needs: Citrus trees will need to be irrigated for their first 3 years. In the drier areas and places with a deep water table irrigation may be needed throughout the life of the tree. Irrigation for most adult citrus trees is 20 liters 3 times a week.

Banana

Musa spp.

Tree Description

Bananas are not really trees but are a large grass species. They are monocots. Bananas are also sterile; although producing both male and female flowers the banana fruit does not contain seed. Bananas will flower after they produce 30 leaves, usually in 8 to 13 months. Male flowers are purple and located at the end of the stem; female flowers are enclosed in bracts containing 6-7 "hands" each with 8-16 "fingers" or bananas. Once the plant flowers, fruit will ripen 5 months later.

Fruit Description

The ovaries contained in the first (female) flowers grow rapidly, developing by parthenocarpy (without pollination) into clusters of fruits, called hands. The number of hands varies with the species and variety. The fruit (technically a berry) turns from deep green to yellow or red, and may range from 2-1/2 to 12 inches in length and 3/4 to 2 inches in width.

Fruiting Data

The male flower always appears first from the center of the stem and the female flowers follow on the same stem. The male flower is large and usually purple in color while the female flowers look like fingers (the bananas). When the length of the stem with the male flower gets to be 20 cm long and many female flowers have appeared the male flower should be cut off where the flower meets the stem. Fruit should be kept out of the sun. Fruit are ripe when they are smooth and have no more angles.

Propagation Data

Bananas are propagated vegetatively either by planting a bulb, a bulb with a sucker, or a bayonet. Usually bulbs are planted two months before the rains because they contain a lot of stored energy and rot easily. This gives them a head start in root formation before the rains arrive. Bayonets, however, need to be planted during the rainy season. Banana plantation holes are 80 cm X 80 cm X 80 cm. The spacing in the plantation should be 2 X 2 meters. Windbreaks are very important. To plant prepare the bulb or shoot by cutting off all the roots any wounds and soaking it in a decomposed manure solution. You also want to promote new growth so cut off any existing shoots and drive a wooden stake into the center of the stem. When planting sink the collar 10 cm deeper into the soil than it was before. When the first sprouts emerge prevent all but the most vigorous from growing. Try to cut them off close as possible to the bulb or the soil surface.

Age before fruiting: Nine months after planting
Fruiting Period: Bananas produce fruit throughout the year

Site Requirements

Wind can be very harmful to bananas and should be avoided. Bananas also do best in sunny areas but cannot tolerate a lot of direct sun (ISRA). They also need shallow water tables (2 - 4 meters).
Preferred Soils: Humid, humus-rich soils
Minimum Rainfall: Optimal monthly rainfall is between 200 to 220 mm
Optimal Spacing: 2 X 2 meters

Tree Care

Mulching is very important and can be done up to 15 cm deep during the dry season. This will also help conserve water. Next generation*:* once the plant flowers the second generation shoot needs to be chosen. Choose the most vigorous shoot and cut off all the rest while the fruit are maturing - these can be sold or transplanted. When the fruit are harvested cut down the parent plant and let the second generation take its place. After three generations the plant should be replanted.
Pruning Period: N/A
Common Pests: *Cercosporiose disease*: caused by a fungus; yellow leaf spots which expand turning gray. In dry conditions we suggest only preventative measures be taken (not watering every day and planting in well-drained areas); *Nematodes*
Irrigation Needs: 20 liters every other day. Susceptible to rotting.
IPM Methods: Do not have plantations in the same place for more than 5 years. The soil in the plantation hole should also be treated.

Papaya

Carica papaya

Tree Description

C. papaya is an arborescent herb with leaves that sprout directly from one central trunk-like stem in a spiral or nearly horizontal pattern. The stem can be from 2 to 10 meters tall and grows quickly. The stem is not woody, but a soft spongy tissue, hollow on the inside and up to 30 to 40 cm thick, and is marked with many leaf scars. The green leaves are 30 to 60 cm wide and are deeply divided into 5 to 9 segments with yellow ribs and veins. Secondary stems will frequently sprout from the main trunk. The leaves and stems contain a type of milky latex. The plant will fruit in 9 to 14 months after seeding and yearly after that.

The flowers can either be female, male, or hermaphroditic, and only one type is found on any given tree. All flowers are fleshy and waxy with 5 petals and a slight fragrance. Female flowers are formed at the base of the leaves, are ivory-white, and have only a pistallate. Male flowers are formed at the end of long stalks (1.5 – 1.8 m long) that sprout from below the leaves and have only a staminate. Hermaphroditic flowers bloom from short stalks at the base of the leaves and are ivory-white with yellow anthers.

Hermaphroditic plants are the easiest to grow for fruit production since they are self-pollinating. If completely self-pollinated the seeds will yield 67% hermaphroditic plants and the rest will be female. Lone papaya trees bearing large amounts of fruit are most likely hermaphroditic. Female plants must be planted near males plants in order to produce fruit. Fruit from a male/female cross will have 50% female and 50% male seed. Male plants will not produce fruit, and if used to pollinate hermaphroditic plants will produce 33% male, 33% female, and 33% hermaphroditic seed.

The solo (hermaphroditic) variety is usually the most desirable as it produces good quality fruit on a short tree that is easy to harvest. When working with solo varieties they must be prevented from cross-breeding with local varieties or their desirable qualities may be lost in future generations.

Propagation Data

Propagation Method: Seed in nursery either in a tree sack or bare root bed. May be direct seeded, with lower success rates

Seed Collection: Collect seeds from mature, ripe fruit. Remove gel from seeds immediately after collecting. Plant the seeds or dry seeds in the shade. Dry seeds will lose viability if not planted shortly after.
Seed Pretreatment: Cold water soak for 24 hours.
Germination Rate: Sow about 4 to 5 seeds per sack at 0.5 to 1 cm deep.
Time to Germination: 15 to 30 days to germinate. If there is a possibility of male seeds, thin the strongest plants right after germination as these are most likely to be male.
Time in Nursery: Outplant after 6 – 8 weeks in the nursery, or when 30 cm tall. Keep in partial shade until 5 – 10 cm tall. When plants are 15 cm tall thin so there is one plant per sack. Papayas can be outplanted at any time of the year since they should be watered all year round.
Grafting Method: N/A
Age before fruiting: 9 to 14 months after planting.

Site Requirements

Preferred Soils: Prefers deep, light, porous soils with a pH between 5.5 and 6.7. Grows well in soil with high organic matter but may produce low quality fruit if improperly drained. Water tables of 2-3 meters are preferred.
Minimum Rainfall: 1500-2000mm per year or heavy irrigation. Requires good drainage.
Optimal Spacing: Plant at 2 x 2.5 meter spacing. The planting hole should be 50 x 50 x 80 cm.

Tree Care

Pruning Period: Dry seasons.
Pruning Frequency: It is recommended to remove all side branches to produce larger fruit.
Common Pests: Papaya plants can attract *nematodes*, which can be a problem when papayas are planted in gardens; *Rhizoctonia* and *Phytophora* fungi; Scales can be a problem and bats are attracted to the ripe fruit.
Irrigation Needs: Nursery: Water lightly; First 2 months: 20 liters 3x week; 3 months: on water 30 – 40 liters every 2 days; Keep trunk dry to prevent rot.
IPM Methods: Nematodes: do not plant papayas in the same spot year after year; sterilize the soil before planting; Neem solution; Rot: make sure the soil is well drained, do not damage the stem; Scales can be picked off by hand or apply soapy water.

Grafting

Grafting is a method of asexual propagation in which a stem or bud (the scion or budwood material) from one variety of a plant is joined to a seedling (the rootstock) of another variety of a compatible species, and the two grow together to become one plant. It allows the characteristics of both plants to be replicated in an adult tree. Usually the scion or budwood and rootstock are chosen for their specific qualities, i.e. a certain variety of citrus rootstock may be chosen because it is resistant to drought and therefore adapted to dryer climates, while the selection of the scion of a certain variety will determine the time of harvest, quality of fruit, or size of fruit.

The Benefits of Grafting include:

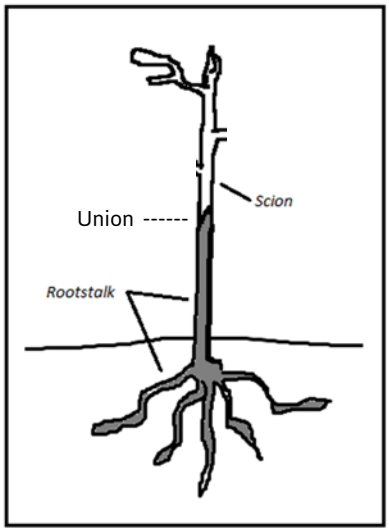
- Faster Fruit Production - grafted fruit trees produce fruit 2-4 years after grafting. Fruit trees that are not grafted typically bare fruit much later, sometimes 7-10 years after they are established.
- Control of Fruit Quality and Quantity – grafted fruit trees bare the same quality and quantity of fruit from which the cutting (scion) was taken.
- Repair of Cambium Damage – trees that have been damaged by rodents or other pests, in cases where the bark and cambium layers have been removed around the circumference of a tree, can be repaired through grafting.
- Increased Tolerance to Climatic Extremes – the root stock of some plants may be better situated for local soil conditions while the growth from a grafted scion is better suited for improved productivity. Grafting provides a means to meet the conditions of both.
- To Maintain or Secure Heirloom or Favored Varieties of Fruits – the seeds of many fruit trees will not produce the same quality of fruit as that from which the seed was taken. Grafting provides a means to reproduce or maintain a desirable variety of fruit.
- Simple Means to Replace Adult Trees with an Improved Variety- replacing one cultivar with another, through topworking, can be performed more easily through grafting efforts rather than replanting each tree.
- Resistance to Disease – it is possible to graft disease-resistant varieties to non-resistant varieties.
- Diversifying Production – through grafting, farmers can diversify their Forest Gardens with different varieties of fruit that produce different qualities and at different times, to take advantage of market conditions.

The Disadvantages to Grafting are that:

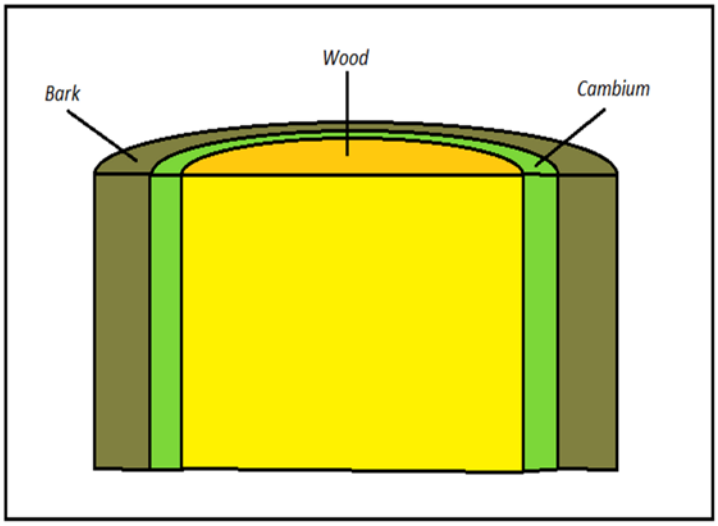
- Grafted plants require more time, care, and maintenance in the nursery than non-grafted trees.
- The life span of the grafted tree is generally shorter than un-grafted trees.

Although many tree species can be grafted, fruit trees are among the most common, since grafted fruit trees yield fruit considerably faster than non-grafted trees. The best fruit species for grafting will depend on the type of fruit you want to produce. The most profitable or desirable products will normally determine which species to graft. Grafted trees improve Forest Gardens by producing a greater quantity of high-quality fruit to consume and sell. Farmers who master grafting techniques can also sell the grafted seedlings that they do not plant in their Forest Gardens.

There are many different grafting techniques. The technique you use is often determined by the species that you are grafting, the time of year, the maturity level of the rootstock, and in some cases your comfort or skill level in one technique over another. With mangos, for example, we encourage a technique called the tongue and groove (or side) graft, and for citrus we recommend "T" budding, chip budding, or side grafting. For *Ziziphus mauritiana* and cashew trees we recommend topgrafting. There are many other grafting techniques as well. The methods discussed in this manual are relatively easy, have high success rates even for beginners, and are generally easy to teach.



Grafted Seedling



Cross Section of Woody Stem

The Principals of Grafting

How Does Grafting Work?

Grafting takes place when two previously unattached trees are connected through a binding process that involves the alignment of their cambium layers. The cambium layer is located just beneath the bark of tree and is responsible for transporting nutrients between the roots and leaves. In a successful graft, the cambium layers between the upper portion of a young tree branch (the scion) and the lower portion of a

tree (the rootstock) are aligned with each other so that nutrients can flow between them. The scion and the rootstock are then bound together to ensure the cambium layers are held intact. A successful union between the scion and rootstock will be noticeable if the scion begins sprouting new growth (shoots and leaves). Depending on the grafting technique performed, the graft can take 2-3 weeks or several months before showing signs of growth. If the graft was a success, the binding material used to tie the scion and the rootstock together can be removed.

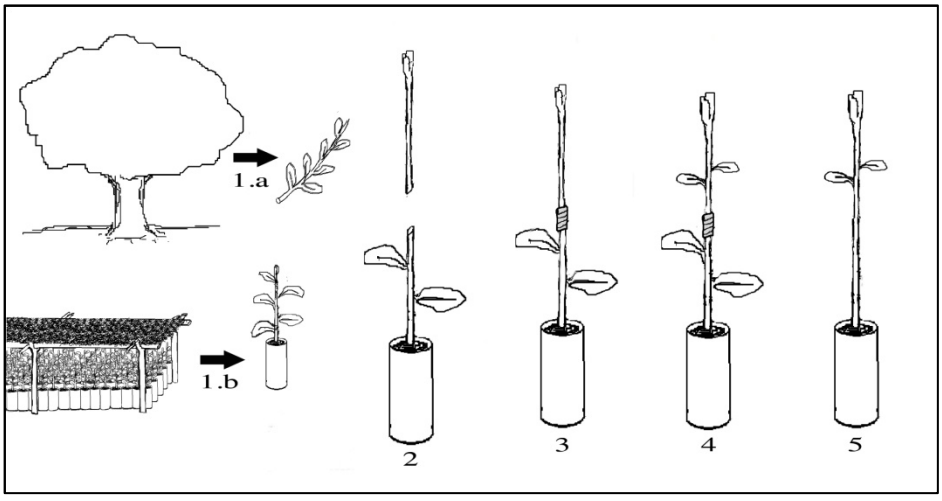
Graft Compatibility

Not every rootstock and scion are compatible with one another. The majority of trees will not form a successful graft with another tree unless they are genetically similar to one another. For example, an apple tree cannot be grafted to an orange tree because they are not closely related. However, one variety of apple tree is likely to graft to another variety of apple tree because they carry similar genes. Before grafting, be sure the rootstalk and scion from the trees you have in mind are compatible with one another. Typically, plants of the same genus and species can be grafted despite being of a different variety. In short: graft mango to mango, avocado to avocado, apple to apple, etc.

The Five Stages of Grafting

There are five basic steps for performing a graft:

1. sourcing the scion and the rootstock,
2. preparing the scion and the rootstock for grafting,
3. grafting the scion and the root stock,
4. waiting for the graft to take and for the scion sprout new growth, and
5. removing the wrapping and maintaining the grafted tree (refer to the figure below).



Scion and Rootstock Selection

The scion or budwood is the source of all of the branches and the top growth that will come after the graft union is made. Characteristics of the adult tree determined by the scion or budwood include the following: type and quality of fruit produced, time of year fruit will ripen, vigor of top growth, and the top growth's resistance to disease and insect attacks. The difference between a scion and budwood is the grafting technique for which it is selected. Grafting uses a scion which is usually a stem about 10 - 12 cm long. Budding is a form of grafting where a single bud, or eye, is attached to the rootstock seedling instead of using a whole stem.

Selecting a Source Tree

The most important aspect of the scion or budwood source tree is that it be the desired variety. The tree should also be completely disease free and should be an adult (producing fruit).

Preparing the budwood and scion selection

Look for a young vertical shoot about pencil width. One thing to look for is that often citrus tends to grow oval or "winged" branches which are more difficult to bud; look for a round branch which will be a lot easier to bud.

For budding, the lateral buds (the buds at the sides of the branch not at the end of the branch) are important. Look for lateral buds which are yellowish in color and ready to push (grow) but not yet pushing. This may be difficult to find. If your source tree is not irrigated and you come too late, during the rainy season when the trees are growing, the buds may have already pushed; likewise, if you come too early, during the dry season, the buds may be dormant. Observe the tree regularly and collect the budwood at the correct time of year when the buds are swelling naturally, usually right before the rainy season, when it first gets humid.
Budwood can usually be found at any time during the year if adequate searching is done.

Preparing the budwood: If the buds are dormant or not swollen at all the budwood should be prepared five to seven days in advance. To prepare the branch, cut off all the leaves and cut off the terminal bud. Be sure to tag the branch that you are preparing because upon return five days later it may be difficult to find. By doing this preparation you are inducing the lateral buds to swell and start to push. If the buds are swollen already the budwood should only be prepared two to three days in advance and the terminal bud should not be removed. If the buds are swollen or already pushing no preparation is needed.

Scion selection: Select a stem in which the terminal bud is swollen but not yet sprouting, particularly with mangoes. If it is already sprouting, after the graft is performed it will continue to sprout before the union of the cambium takes place. The graft point is unable to take up nutrients and will die because all the energy is going into the growth of the sprout. The scion should be somewhat lignified (green tender wood). If the scion

is not lignified, it will dry out and wilt before the union of the cambium layers takes place. The scion should be equal in diameter to the rootstock stem or smaller but never larger. Avoid scions with weakly developed terminal buds. Terminal buds should be rounded, not angular. Use scions which are already swollen naturally. After removing the scion from the tree, carefully remove any leaves and their stems from the scion. Dot collect scions when flowers on the tree are developing.

Selecting the Rootstock

The rootstock determines the bottom growth which includes the following characteristics of the adult tree: the form of root growth, the root's resistance to diseases, insect attacks, drought and other environmental conditions, and vigor of the tree.

Your rootstock should be graft-compatible with the tree you want to replicate. It is also good practice to source the rootstock from an area similar to where you want to transplant the grafted tree to be sure it is well-suited to that environment.

If you are collecting your rootstock from a tree nursery for grafting, select a healthy, vigorous seedling produced from seed collected from vigorous trees adapted to the local enviornment. Choose seedlings that have diameters of 1 cm or more halfway up of their stems. You can also dig up seedlings from a field or forest if you find the species you would like to graft, or graft directly onto a young tree that is already growing in a desirable location.

Grafting Techniques

There are many types of grafting methods. This manual will cover a handful of commonly used grafting techniques: bud grafting (including T-budding and chip budding techniques), side grafting, and topworking. Bud grafting is a type of graft where a single bud is attached to the rootstock, instead of using a full scion. The grafting method you chose will depend on your skill level, resources, and the time of year you want to graft.

Tools and Materials

The following tools and materials are needed to perform a graft. You should always use a clean, narrow, very sharp blade for making cuts to prevent wounding the tree more than needed, which will minimize exposure to pests and disease and enhance the healing process. Always clean the blade with alcohol before making cuts, to avoid the spread of pathogens that could infect your grafted trees.

- **Grafting knife:** if you do not have a sharp grafting knife, a utility knife with a sharp blade will work
- **Grafting tape:** if not available, thin plastic (about 3-5 cm in width) will work, e.g. strips of plastic cut from material used to make tree sacks
- **Grafting compound:** beeswax can be used as a grafting compound. It isn't necessary, but it does help to protect the graft union as it sets, if available

- **Alcohol:** used to clean the grafting knife before making any cuts, to prevent spread of disease
- **Scion or budwood:** see 'Selecting the scion or budwood' section above
- **Rootstock:** see 'Selecting the rootstock' section above

Bud Grafting

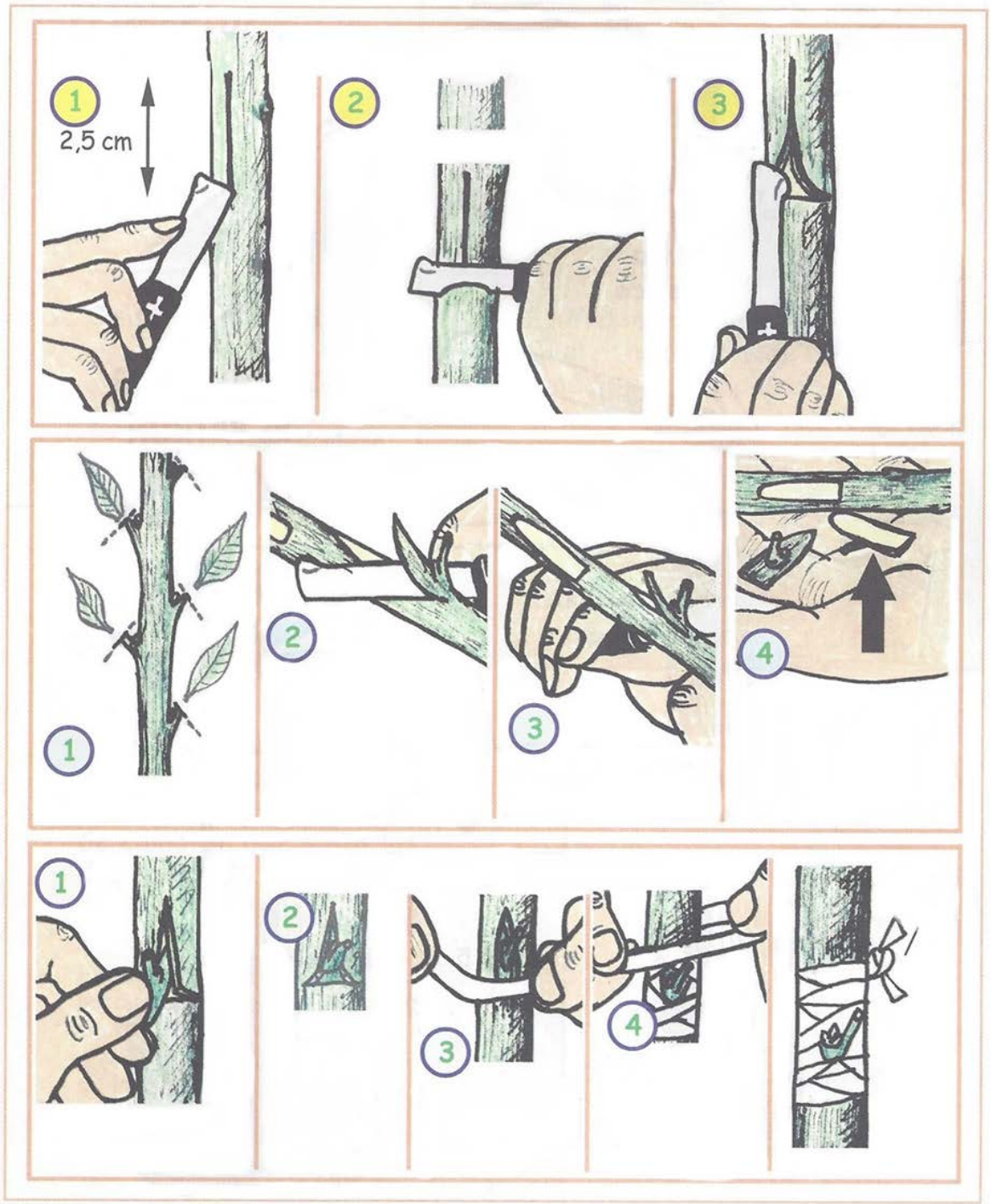
Bud grafting is the process of taking a bud from the desired scion and attaching it to a suitable rootstock. Because a bud is much smaller than a scion used for the side grafting method, the bud graft method is used for the harder wood species like citrus. However the bud method can be effectively performed on mangos as well. This method is also much faster to perform than the side grafting method but because of its size it offers less surface area to match up all the layers. Furthermore in case of bud wood, the aligning and wrapping rules for bud grafts are essentially the same as for the side graft, described below.

"T" Budding

1. Prepare the rootstock
    - Select a flat area about 30-50cm above the soil surface. After cleaning your knife, cut off all the leaves, thorns, or branches around the grafting site. Make an incision about 4-5cm long and 3-4cm across in the shape of a "T."
    - Carefully open up the "T" by spreading the bark apart with your knife. If the bark does not want to slide off the woody part, the tree needs to be better irrigated and some compost or manure should be added to the soil.
2. Prepare the budwood
    - Now collect the bud from the budwood. Starting 1-2cm below the bud, in one smooth motion cut into the budwood and upward. Cut until it is about 3-5cm above the bud. Never handle the bud by the back side – either use the leaf stem or the tail tip.
3. Form and protect the union
    - Gently insert the bud into the "T" incision. Be sure that the bud itself is in the center of the "T" part.
    - Cut off the "tail" of the bud. Make sure it is even with the horizontal incision and there is a snug fit.
    - Starting below the bud site, tie some grafting tape or thin plastic wrap. Wrap the site as tight as possible. Do not cover the bud itself. Make sure to cover the whole wound except for the bud. The bud can be left uncovered, <u>or</u> take another plastic strip and wrap loosely over the bud and tie.
4. Post-graft maintenance
    - Come back a week after grafting. Uncover the bud (if covered) but leave the "T" wrapped. If the bud is still green but not taken, bend the rootstock stem away from the direction of the bud about 10-15cm above the bud site.
    - When the bud sprouts, cut off the rootstock stem 20cm above the bud site and unwrap the rest of the plastic wrap. Tie the bud (scion) to the rootstock to encourage straight growth and to protect it from breaking. When 20-30cm of

new growth occurs, cut the rootstock off flush above the bud point.

Refer to the diagram below to see the steps in T budding:



Chip budding

1. Prepare the rootstock
   - Make a 45 degree angle incision about ¼ through the stock.
   - About 2.5 cm (1 inch) above the first cut, make a second cut going downward and inward until it connects the first cut.
2. Prepare the budwood
   - Remove the bud from the budwood similar to the cut you made on the rootstock.
   - Make the lower cut about 0.6 cm (1/4 inch) below the bud.
   - Make a second cut about 1.3 cm (1/2 inch) above the bud coming downward behind the bud and connecting with the first cut, permitting the removal of the bud piece (or chip).
3. Form and protect the union
   - Gently insert the bud piece flush with the incision in the rootstock.
   - Starting below the bud union, tie some grafting tape or thin plastic wrap. Wrap the site as tight as possible. Do not cover the bud itself. Make sure to cover the whole wound except for the bud. The bud can be left uncovered, or take another plastic strip and wrap loosely over the bud and tie.
4. Post-graft maintenance
   - Come back a week after grafting. Uncover the bud (if covered) but leave the grafted part wrapped. If the bud is still green but not taken, bend the rootstock stem away from the direction of the bud about 10-15cm above the bud site.
   - When the bud sprouts, cut off the rootstock stem 20cm above the bud site and unwrap the rest of the plastic wrap. Tie the bud (scion) to the rootstock to encourage straight growth and to protect it from breaking. When 20-30cm of new growth occurs, cut the rootstock off flush above the bud point.

Side Grafting

The side graft is a useful, relatively simple graft that is commonly used on mango seedlings and other young seedlings with thin stems. A commonly used technique for the side tongue graft is to create a whip and tongue between the rootstock and scion to increase the integrity of the union and the surface area where the cambium layer aligns.

1. First prepare the scion (see 'Scion and Rootstock Selection' section above). The scion will stay on the tree for approximately a month, allowing the buds to swell. After the scion is removed from the tree with a clean, sharp knife, it is ready to be prepared for attaching it to the rootstock.
   - Pick a flat part of the scion, between the nodes, approximately 5-10 cm below the scion apex. This is where your first cut will be made.
   - Using steady pressure, begin by making a cut 3-5 cm long from shallow to deep. Turn the scion over and make a smaller cut (approx. 1 cm) to form a wedge that will fit into the rootstock.
   - Set the scion aside.

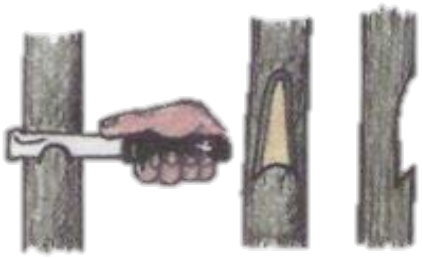
2. Prepare the rootstock:
    - Remove all leaves from the intended rootstock seedling or plant.
    - Choose a spot on the rootstock that is semi-lignified and at roughly knee height. While it isn't crucial that both the scion and the rootstock are the same diameter at the point of the graft, the closer in size they are the better chance the graft has of taking.
    - Make your first cut deep and at a 40-degree angle. This is where scion will fit into so try to make the cut identical to the shorter cut on your scion.
    - Next move your knife 3-5 cm above your 1st cut and with steady pressure make a cut, shallow to deep. The end of the 2nd cut should match up with the end of the 1st cut.
3. Attach and Align the Scion
    - Place the scion into the cuts on the rootstock, making sure to match up the cambium layers. If your rootstock is larger than your scion, the graft is still possible. Simply line up the scion to one side of the rootstock cambium. This is also your chance to make any touch up cuts to either the rootstock or the scion to make them fit together better. To ensure that the scion does take, there should be no gaps between the scion and the rootstock, so it is very important to make touch up cuts where needed.
    - When you are confident that the cambiums are matched as best as possible, you can begin wrapping the graft with clear-plastic strips. Using clear plastic is important because it allows you to look at the graft while it is still wrapped. Begin the wrap below the graft, making sure to wrap tightly, leaving no gaps. Then continue up the graft, wrapping tightly and overlapping each plastic layer. Having an airtight seal is very important because the graft is very vulnerable to pests, diseases, desiccation, as well as rotting from standing water. Once you reach the apex of the scion, wrap loosely but be sure to keep the airtight seal. As the scion takes and begins to grow, the buds on the apex will begin to grow and will need some room. After you have wrapped passed the apex, wrap tightly again and tie off the plastic.
    - Lastly, remove all but a few leaves above the graft and cut the terminal bud on the rootstock. Leaving a few leaves will allow the rootstock to pump up much-needed nutrients and water to accelerate the grafting process, while removing the terminal bud will trick the plant into sending growth hormones to open new buds. The entire stem above the graft will be removed in a few weeks when the graft has taken, but for now it's serving a purpose.
    - To make sure you did a good job, the next morning revisit your graft and check for moisture droplets inside the plastic. If you have moisture condensation within the plastic that means your seal is effective and you won't have to rewrap the scion. If there is no water however, take the plastic off and try again.
4. Post-graft Maintenance
    - The graft will require a few weeks to take so check it once every week or two. You will know if the graft took by the sprouting of buds on the apex of the scion. Healthy scions will also remain green; whereas bad scions will have

turned black and dead looking. If a graft is unsuccessful, further attempts can be made to graft the same rootstock.

- Once the buds on the apex have sprouted (4-5 weeks), remove the plastic above the apex, allowing it to continue to grow, but leave the rest of the graft wrapped. The scion is still in a weak state at this point and needs the support of the wrapping.
- When the scion is producing green leaves (not purple) the wrapping can be removed and the rootstock stem above the scion cut off. Grafting compound can be added where available.

Side Grafting

Rootstock Preparation



Front view

Side view

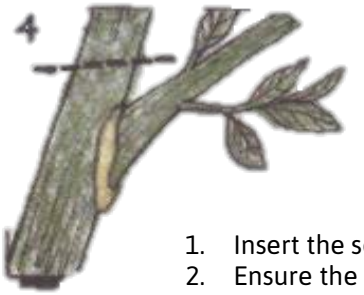
Scion Preparation

Side view

Back view

Front view

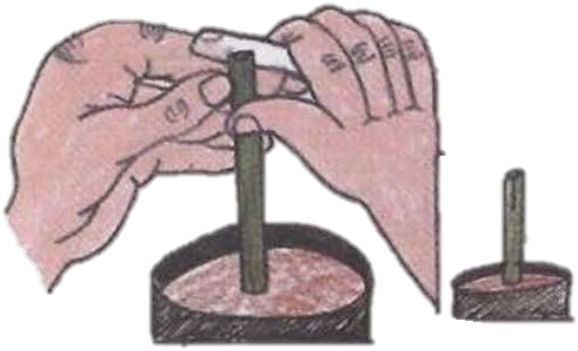
Make a downward cut 2.5-4 cm long

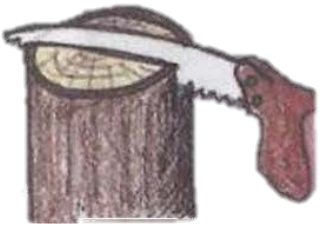


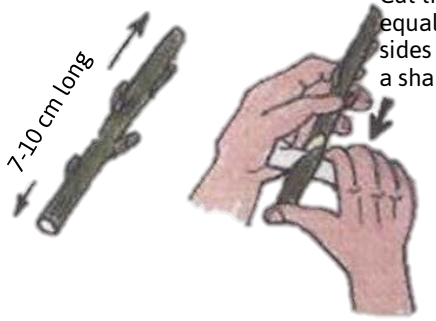
1. Insert the scion onto the rootstock.
2. Ensure the cambiums line up.
3. Wrap tightly with plastic wrapping.
4. After the scion begins to grow, cut off the rootstock above where it was grafted.

Topworking

Rootstock Preparation



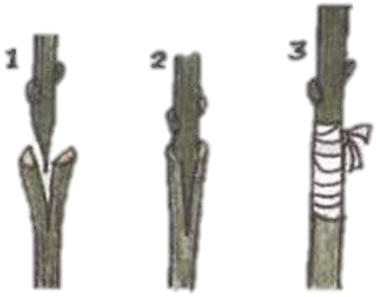




Cut the scion equally both sides to make a sharp point

Side view

Front view



1. Insert the scion in the rootstock.
2. Line up the cambium layers
3. Wrap tightly the plastic

Use wax to seal the grafts for larger trees

A successful top graft on a young seedling.

Topworking

Topworking is used on mature plants which are to be changed to a different cultivar. This method should be limited to stock branches about 2.5 to 10cm in diameter and to species with fairly straight-grained wood that will split evenly. Topworking can be done any time during the dormant season (dry season), but the chances for a good union are best if the work is done just before the active growth has initiated (just before raining season) and buds of the stock are beginning to swell. In making the graft for top working the proper placement of the scions is very important. (See figure below). The scions should be made from one year-old wood. The scion is made by cutting a long, gradually tapering wedge. Preparing the stock it is important to split the stub deeply (even split). Two scions are inserted in the stub, one at each end of the split. The scions must be carefully placed so the cambium layers match. Add grafting compound where available when the grafts are set to protect the graft unions.

CHAPTER 6: REFERENCES

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