High Health Grafting and Budding

Grafting is a vegetative, asexual plant propagation technique, which has been practiced for centuries. It is mainly used in fruit tree crops to maintain or increase fruit yield and quality, provide resistance to disease, and adaptability to soil conditions. It is also now used for propagation of some forest trees and ornamentals. Grafting has also become a means of managing soilborne diseases in vegetable crops, especially in Cucurbits and members of the Solanaceae family. Grafting and budding is a major strategy for overcoming many devastating plant pathogens. That said, it has also been responsible for the dissemination of many serious plant diseases.

Selection of good propagation material is arguably the most important task for the propagator. Having a clean source of rootstock (seed, cuttings or tissue-cultured plants) and scion material, is essential in achieving high health propagation. Care must be taken to select source trees free from viruses, viroids and phytoplasmas as well as latent pathogens. Mother stock material also must be healthy, free of non-pathogenic disorders, particularly water stress, and insect and mite pests.

This factsheet summarises simple methods to maximise the production of high health grafted and budded nursery stock that are free of diseases. It also summarises the major pathogen groups that can be spread in grafted stock and how to avoid doing so. A great deal of information on grafting and budding techniques is available online (see further reading) and is not covered in this factsheet.

Grafted cherries. Photo by Fleming's Nursery.

A SHORT HISTORY OF GRAFTING

Stem and root grafts occur naturally. Stem grafts can occur where trees grow very close together and effectively form a graft. While this is relatively uncommon, there is speculation that the observation of natural grafts is how grafting was borne into horticulture. Root grafts, however, are widespread and occur within and between plant species in forests and orchards.

The earliest verifiable record of grafting for plant propagation dates back to about 400–500 BC suggesting that it was widely practiced in that era, e.g. in Greece and Persia. Prior to this there are references in ancient Biblical times implying that grafting may have been practiced. Other regions such as China probably also grafted plants during a similar time period but written records are somewhat dubious. In all likelihood it began independently in multiple regions of the world thousands of years ago.

Root grafts can be an important mechanism of spread for virus/viroid and vascular wilt diseases. For example, the Dutch elm disease fungus *Ophiostoma ulmi* can gain entry into healthy trees through vascular connections that occur when roots from a diseased tree naturally graft with those of a healthy tree. Avocado sunblotch viroid (ASBV) is transmitted by naturally occurring root grafts between avocado trees. Spread of *Citrus exocortis viroid* can also occur in citrus orchards by naturally occurring root grafting.

CURRENT DAY GRAFTING

Today grafting is commonplace for tree crops and increasing in use for vegetables (particularly for plants in the families Cucurbitaceae and Solanaceae). Some ornamental nursery stock lines are also grafted. Plants are grafted for many reasons including the following benefits.

- To preserve sought-after characteristics in fruit trees, particularly higher production and improved fruit quality.
- To reduce or eliminate a prolonged juvenile phase before they produce fruit; grafted ornamental plants will flower earlier.
- To dwarf fruit trees to allow for high density plantings.
- To produce plants with unique growth forms, e.g. weeping or cascading plants.
- For ease of propagation where cuttings may be difficult to strike.
- To improve uniformity of seedling production.
- So that plants can be adapted to different soil types, i.e. with root stocks with different soil tolerances to waterlogging, poor soil aeration, salt content, etc.
- To increase plant longevity.
- For disease resistance. For example citrus rootstocks provide tolerance to *Citrus tristeza virus* (quick decline, stem pitting), tolerance to *Phytophthora* root and collar rot, and give good fruit quality and horticultural performance.

Grafting can also be used for research purposes to test translocation of plant metabolites. Production managers can use grafting to test if unusual symptoms can be transferred between plants. Most pathogens will be transferred via grafting. Some symptoms caused by non-pathogenic factors can also be moved between scion and root stock, particularly if it involves the translocation of a chemical product, e.g. some herbicide, plant hormones, alkaloids etc. By grafting symptomatic and asymptomatic scions to symptomatic and asymptomatic root stocks, perhaps of the same or different varieties, it can sometimes reveal information about the source of symptoms. This information can then be used to better manage the problem.

GRAFT COMPATIBILITY

Graft compatibility generally refers to the establishment of a healthy graft union that provides for the extended survival and function of the grafted plant. The scion and rootstock must be closely related. Grafts of the same variety and species are almost always compatible. Grafts of different varieties within the same species are nearly always compatible. Grafts between different species in the same genus are often compatible but grafts from different genera

Healthy mango seedling, 3 months after grafting.

Graft overgrowth (as shown on this avocado) can sometimes limit production. Photo by Elizabeth Dann, University of Queensland.

Successfully established graft on a mature avocado.

within the same family are rarely compatible. There are no verified records of compatible grafts for plants from different families. Inter-species graft incompatibility can result from physiological rejection that can be rather unpredictable. In addition to taxonomic relatedness, rootstock and scion age and juvenility can effect graft compatibility. Furthermore, healthy graft material in the correct physiological state (dormant or actively growing) is very important to produce a successful grafted plant.

When selecting rootstocks, the rootstock/scion combination must be considered in total. The performance of the rootstock alone gives no indication of how it will interact with a particular scion. For example if the avocado variety Hass is grafted to the *Phytophthora* resistant avocado rootstock Martin Grande, fruit yields are very low. Also physiological incompatibility can occur in combinations that are technically graft compatible. Such combinations are not suitable for horticultural production even though the graft is healthy. It is therefore important to test new combinations under field conditions for an extended period of time to fully understand how it will perform. For more information on graft compatibility refer to further reading.

SELECTING HEALTHY, PATHOGEN-FREE GRAFTING MATERIAL

Any pathogens present in either scion or root stock material will continue to be present in the grafted plant, even if no disease symptoms are present at the time of grafting. It is important to reduce disease pressure when selecting grafting material by practicing strict hygiene procedures. The following recommendations will maximise the health of grafted plants and are also relevant for propagation of grafted or budded plants and cuttings generally.

Scion material must be selected from healthy trees that are not water stressed and are free from pests and diseases. It is recommended to monitor tree healthy regularly leading up to collection of scion (and rootstock) material. Ensure that growing tips and foliage are free of insects and mites. This can be completed by plant beating and close examination using magnification (hand lens and microscope if necessary). Plant beating involves gently but firmly hitting foliage onto a tray, bucket, laminated paper or other uniform surface. Many insects and mites can be monitored efficiently in this fashion. For high risk hosts and pests however, it is also worthwhile to collect a number of samples and examine them under a microscope to verify that pests are not present. Assign greater monitoring effort to higher risk plants and pests or stock of high economic value. Small populations of pests such as scale insects and broad mites can cause massive problems for nursery stock, particularly if the central leader is significantly damaged. Regular monitoring 2–3 months prior to collection of material allows for enough time to get mother stock plants in optimal condition and maximise success of grafted plants.

Other guidelines that will minimise disease in grafted plants:

- **Avoid trees with dieback, stem cankers** and excessive dead leaves as fungi can be present within the tree, even in branches that appear healthy. Cuttings taken from such plants are high risk and may cause graft failure or increase disease incidence during periods of plant stress, perhaps even years after leaving the nursery.
- **Do not cut graft material in the rain** or when material is wet. Fruiting bodies and other infectious material will be present on dying or dead stems and leaves. These spores are released in wet weather, and may infect unprotected, new wounded tissue on the scion material. This can result in graft failure.
- Regularly **disinfest secateurs** with 10% commercial bleach (i.e. 1% available chlorine), for 30 seconds particularly when moving between plants.
- Collect material to **avoid heat and wind** that can cause desiccation as material is cut from the tree.
- **Do not collect material contaminated by soil/media splash**. Bacteria and fungi can be present that can colonise wounds and increase graft failure (even if they are not primary plant pathogens). Take material from the middle or upper part of source plants or trees. If mother stock plants are ones that grow very close to media surface it may be worthwhile to use pot covers that reduce or eliminate media splash (typically used for weed management).
- Use new or **clean bags/containers** for collecting scion material.
- **Surface disinfest scion material** if required. Also consider if application/s of pesticides (to manage insects/mites and fungal pathogens) is required particularly in source blocks with low levels of pests. This may help reduce pest infection in nursery stock in the future.

PROVIDING HEALTHY ROOTSTOCKS

High quality root stock material is also required to produce a successful grafted plant. Seed should be used from plants that are known to be healthy and free of disease. It is important to understand the range of pathogens that may be present in seed of the crop in question, as well as their severity and the length of time they take to produce symptoms. This will assist in assessing the level of risk and the amount of effort to be spent testing that plants are pathogen free. Some industries have certification schemes to ensure that nursery stock are pathogen free, e.g. citrus and avocado.

The following guidelines will minimise disease in grafted plants:

- All equipment (secateurs, pruning tools, harvesting clippers) should be regularly cleaned and disinfected.
- Infected trees in source blocks must be immediately destroyed. Only collect seed from healthy plants.
- For tree crops, seed used to produce a rootstock must be extracted from sound fruit harvested directly from the tree. Low hanging fruit that is contaminated by soil splash has a higher risk of pathogen infection. Obviously this is not possible for cucurbit crops where fruit sit on the ground.
- For all crops, ensure that fruit or seed-bearing plant material is healthy and free of disease.
- The seed of some crops require special treatment, e.g. the seedcoat of avocado should be removed prior to planting or the risk of disease increases dramatically.
- If sufficiently high quality seed cannot be consistently obtained, heat or chemical treatment of seeds may be required to disinfest pathogens present. Not all pathogens can be eliminated in this way. Seek information for your particular crop and pathogen to better evaluate your options.

NURSERY HANDLING

Grafting material should be transported to the nursery as quickly as possible under cool conditions, but ensure they do not freeze. Freezer blocks should be wrapped in paper and placed in unused zip-lock bags to avoid direct contact with material (which could result in cold damage). Containers used for transport should be clean, either unused and free of all organic material, or disinfested with bleach as per guidelines above. Grafting material that comes in contact with soil should not be grafted and ensure all working surfaces and propagation tools are regularly disinfected.

Once in propagation, actions that will maximise crop health and minimise disease pressure include:

» Practicing high hygiene standards including removal of weeds and vegetative debris in and around the nursery.

» Maintain optimal plant growth.

» Restrict access to essential, trained personnel whenever possible.

» Do not injure stems of plants in the nursery.

» Grafted nursery plants with necrotic tissue at or near the graft union should be immediately destroyed, and surrounding plants sprayed with an appropriate fungicide.

» Discard nursey stock which has been kept well after the intended dispatch date, such plants become pot bound, stressed and are more likely to be infected with latent pathogens.

Grafted *Pinus* sp. trees. Photo by HQPlantations

FIELD ESTABLISHMENT

The importance of using pathogen–free propagation material when establishing new plantings cannot be overstated. Accreditation schemes for healthy grafting material and nursery plants have been very successful for industries such as citrus and avocado.

When planting grafted plants, in the field, the graft union must remain above the soil line, otherwise the scion will produce roots that grow into the soil. This is particularly relevant to grafted vegetable seedlings, where grafting is being used to manage soilborne diseases such as Fusarium wilt or *Phytophthora* species. High grafting to prevent soil splash may be required for some plants.

Young trees with latent or wound infections at the graft union may develop cankers after field establishment. Such trees should be destroyed, though it may be worthwhile to have the pathogen involved identified by a diagnostic laboratory. This may assist in establishing the source of infection and better management of remaining plants. Removing the scion and regrafting onto the rootstock (reworking) may result in reinfection of the scion and therefore is not recommended.

It is recommended to clean and disinfest pruning tools, harvesting clippers, tree injection and other equipment on a regular basis and after use with plants suspected to be infected with plant pathogens.

MAJOR GROUPS OF GRAFT TRANSMISSIBLE PATHOGENS

VIRUS, VIROID AND PHYTOPLASMA

Virus, viroid and phytoplasma are all graft transmissible plant pathogens that can cause major crop losses and tree death. For crops for which these are serious pathogens, it is essential that scion wood and buds are taken from trees that are pathogen-free. Current day testing normally involves molecular tests to index mother stock material, though other methods are possible, e.g. grafting or budding scion material onto an indicator variety which reacts quickly and characteristically to the specific pathogen in question. Based on these results source trees should be managed strictly to remove infected trees. Trees usually require testing every 3–5 years. "Foundation trees" in certification schemes are often kept in insect proof repository houses to reduce the pressure from vector based pathogens. Whenever possible, it is recommended to use varieties that are resistant to these pathogens.

The passionfruit scion is rotting due to infection by *Phytophthora nicotianae*. The rootstock is resistant.

Graft dieback in seedling avocado.

Indexing of source trees is used, for example, to provide propagation certified material for citrus, avocado, stone and pome fruits. Auscitrus supplies citrus material tested and found free from *Citrus exocortis viroid*, *Citrus psorosis virus* and other graft transmissible pathogens. Grapefruit trees, however, are actually immunised with a mild protective strain of *Citrus tristeza virus* to protect against severe stem pitting strains of the virus. This is technically known as mild strain cross protection.

Avocado nurseries select propagation material from trees that have been tested and found free of *Avocado sunblotch viroid*. Source trees can be symptomless carriers of the viroid, and this viroid can be spread on contaminated cutting and pruning tools. Seed transmission of the viroid can be as high as 80–100% in avocado trees with visible symptoms, and 5% in asymptomatic trees.

Passionfruit nurseries manage *passionfruit woodiness virus* by carefully selecting scion material from areas where severe strains of the virus are not common. This virus is not seedborne, so seedlings used as rootstocks will be free of the virus provided they are not grafted with infected scions.

LATENT PATHOGENS

Many woody plants, especially those derived from cuttings, or grafted trees, may have fungi or bacteria existing as endophytes or latent pathogens residing in their internal tissues without causing symptoms. There can also be direct infection by fungal spores and bacterial cells through graft wounds and wounds on young stems. Members of the Botryosphaeriaceae are a good example of these types of infection. They have a latent phase where there are no visible symptoms, but are able to become very aggressive plant pathogens when the host plant is stressed by drought, a nutrient deficiency, waterlogging, temperature extremes, or damage by insects or other pathogens. They can be moved extensively in nursery plants when in the endophytic stage. They cause various disease symptoms which include twig and branch dieback, main stem cankers, collar rots and failure of graft unions. They can also cause widespread damage if they spread to susceptible hosts nearby.

Generally, certification schemes do not consider latent pathogens that live endophytically in healthy plant tissue. The main reason for this is that they are virtually impossible to detect when asymptomatic. Furthermore, there are many species from diverse groups that can potentially act as latent pathogens. For more information on this topic refer to the nursery paper on latent pathogens.

BIOSECURITY

Diseases caused by systemic pathogens, like those that can be spread in grafted plants, are arguably the most serious of all plant crop diseases. These diseases cannot be cured and often either severely reduce yield or cause plant death. In general, infected trees must be destroyed. Many very serious systemic diseases could enter Australia in nursery stock. Once introduced they can be transmitted on grafting knives, hedging equipment and may have insect vectors. Examples include such diseases as Huanglongbing (*Candidatus Liberabacter asiaticus*), Pierce's disease (*Xylella fastidiosa*) and many others.

If you observe plant symptoms that you suspect may be caused by an exotic plant pathogen, call the Exotic Plant Pest Hotline on 1800 084 881 and or submit a sample to a diagnostic laboratory for identification.

FURTHER READING:

There is a large volume of literature available on grafting techniques. Below are just a small number that may be helpful.

- A history of grafting
- Grafting/budding techniques
- Grafting technique videos
- Heat treating seeds
- Grafting manual for vegetable crops

This document was prepared by Ken Pegg, Andrew Manners and Sarah Dodd (Agri-science Queensland, Department of Agriculture and Fisheries, Ecosciences Precinct, GPO Box 267, Brisbane QLD 4001) as part of the nursery levy and Hort Innovation funded project Building the resilience and on-farm biosecurity capacity of the Australian production nursery industry (NY15002) in 2019. All photos by DAF, unless otherwise stated.