Grapevine Propagation; Principles and Methods for the Production and Handling of High Quality Grapevine Planting Material

Helen Waite[1*], David Gramaje[2] and Lucie Morton[3]

[1]National Wine and Grape Industry Centre, School of Agricultural and Wine Sciences, Charles Sturt University, Wagga Wagga, NSW 2678, Australia

[2]Department of Crop Protection, Institute for Sustainable Agriculture (IAS), Spanish National Research Council (CSIC), Alameda del Obispo s/n, P.O. Box 4084, 14080 Córdoba, Spain.

[3]Viticulturist, Charlottesville, Virginia, USA.

*Corresponding author hwaite@csu.edu.au

Contents

Introduction

This paper has been written in response to concerns regarding the transmission of debilitating grapevine trunk diseases in grapevine propagating and planting material that have been raised by trunk disease research scientists, grapevine nurseries and grape growers in many parts of the wine producing world.

This paper is presented as a common starting point for propagators, grape growers and scientists to support the production of planting material that is of the highest quality. It has been produced with due care, but it is general in nature only and should be used in conjunction with plant propagation texts, peer reviewed papers and within the context of the regulatory environment of each country, state or district that governs the production of cuttings and vines and their movement across regulatory boundaries. The use of this document is not compulsory and is not presented as a set of rules. However, it is based on the results of scientific research and discussions with the nursery and grape growing industries around the world over many years and is designed to be used as a basis for the development of standard operating procedures for vine propagation and vineyard establishment.

Part 1: Quality Criteria for *Vitis vinifera* and Rootstock Cuttings Entering the Propagation Chain

Introduction

The quality of cuttings entering the propagation chain is fundamental to successful propagation. A quality cutting is one that performs to expectations in the nursery and has the capacity to become a healthy, vigorous vine of known type that will perform to expectations in the vineyard.

A quality cutting has both visible characteristics and intrinsic characteristics that cannot be seen by looking at the cutting, but are as equally important as the visible characteristics.

Intrinsic characteristics of Good Quality Vitis vinifera *and rootstock cuttings*

Quality *Vitis vinifera* and rootstock cuttings:

1. Are of known variety (and clone if applicable).
2. Are from a registered source block that is comprehensively inspected at least once a year in the growing season and randomly sampled for the presence of:
    a. Serious virus diseases such as the ones caused by Nepovirus (GFLV, ArMV), Ampelovirus (GLRaV-2), Closterovirus (GLRaV-1, 3) and Vitivirus (GVA) .
    b. Fungal and bacterial trunk diseases including black-foot and Petri disease pathogens, Botryosphaeriaceae spp., crown gall etc.
    c. Other fungal pathogens such as *Botrytis* spp., *Phomopsis* spp.
    d. Invertebrate pests such as phylloxera, scale and mealy bugs.
    e. Parasitic nematodes (*Xiphinema index*, *Meloidogyne* spp. etc.)
3. Clearly labelled, with the correct variety and clone (if applicable).
4. Clearly labelled with the batch number and accompanied by appropriate electronic, hard copy documents or reference numbers that include, or enable ready access to:
    a. Record of the origin of the cuttings;
    b. Date of despatch;
    c. Method of transport and conditions during transport including packaging, refrigeration, time in depots;
    d. Quarantine documents if applicable;
    e. Plant health certificates if applicable.
5. Have not been exposed either by direct contact or fumes, to herbicides, ethylene or petroleum products.
6. Have not been allowed to overheat above normal winter ambient temperatures or been exposed to temperatures below 1^{o}C at any stage.
7. Have been packaged without free water in the packaging, but in a manner that avoids dehydration and oxygen starvation.

8. Have been transported in a manner that avoids delays and meets the conditions described in points 5-7 inclusive.

Visible Characteristics of good Quality Vitis vinifera *and Rootstock Cuttings*

Quality dormant cuttings are:

1. Fully lignified with tightly closed buds.
2. A good bright brown or tan colour; not blackened by soaking or bleached.
3. Free of signs of external pathogens such as *Botrytis* spp., powdery mildew and *Phomopsis* spp.
4. Neither 'rank' with excessively long internodes or stunted with excessively short internodes, but with internodes of moderate length as appropriate for each variety.
5. Of an even size 5-12 mm in diameter measured just below the top node.
6. Not damaged by trellis wires, machinery or vermin etc.
7. Free of invertebrate pests such as mites and mealy bug.
8. Free of dead leaves, soil and other debris.
9. Straight or with only a slight curve; 35-40cm in length.
10. Straight cut, 25mm below the bottom bud, and a sloping cut at 45° 30 cm above the top bud, with the high side of the cut on the same side as the bud.

Part 2: Quality Criteria for Rooted Nursery Vines Ready for Planting in Vineyards

Introduction

A quality nursery vine ready for planting is one that is of known type, healthy and vigorous, establishes quickly and performs to expectations in the vineyard.

The quality of rooted nursery vines is dependent on the quality of the rootstock and *V. vinifera* cuttings entering the propagation chain and subsequent nursery management practices.

A quality vine has both visible and intrinsic characteristics.

Intrinsic Characteristics of Good Quality Nursery Vines

Good quality vines have the following intrinsic characteristics:

1. Should originate from a nursery that subscribes to a quality assurance scheme and is audited regularly by an independent authority.
2. Should be derived from propagating material (cuttings) obtained from registered source blocks that are inspected annually and tested for pests, diseases and off types.
3. All bundles of vines should be appropriately labelled with the name of the nursery, batch number, variety, clone and rootstock.
4. All vines are accompanied by electronic and/or hard copy documents or reference numbers that enable trace back through all processes of the propagation chain to the source blocks of origin.
5. All vines should be accompanied by relevant documents relating to quarantine requirements if applicable.
6. All vines should be packaged in a manner that allows good ventilation without resulting in damaging dehydration.

Visible Characteristics of Good Quality Vines

All Material

Good quality vines have the following visible characteristics:

1. Vines should be of an even size and vigour. Trunks should be not less than 7 mm in diameter and not greater than 14 mm and straight or with only a slight curve.
2. Vines should be free of signs of disease such as powdery mildew, botrytis bunch rot and blight and Phomopsis cane and leaf spot. Vines should be free of signs of invertebrate pests including nematodes, scale and mealy bugs.
3. Vines should not be broken or damaged.
4. Each vine should have at least 1 well-developed shoot with healthy buds.
5. Each vine should have at least 3 healthy, undamaged, evenly spaced roots.
6. The surface of the vines should be a good bright colour and not blackened or soggy or covered in large amounts of mould.
7. Vines should not show signs of dehydration such as shrivelling.
8. Vines should have a pleasant earthy aroma and should not smell of fermentation (winey aromas) when packaging is opened.
9. There should be no signs of brown or black spotting or streaking in a cross sectional cut of the tissues of trunks, canes and roots. Discolouration that extends beyond the immediate area of a wound including cut ends and disbudding wounds is indicative of trunk diseases such as black-foot and Petri diseases, Botryosphaeriaceae spp. etc.

Grafted Vines

In addition to the above criteria, grafted vines, whether green or dormant, should also conform to the following standards:

1. Grafts should be fully healed, not overgrown and not able to be broken by “moderate” pressure applied by the thumb.
2. The interior of graft unions should not be contaminated with organic or inorganic substances such as grease, callusing mix, budding tape or ties. Contaminated graft unions show heavy dark brown or black discolouration in the wood extending away from the union. Darkening in the tissue associated with healing of the graft union

should be small in extent and highly localized and not extending beyond the area of the graft union.

3. Disbudding wounds on rootstocks should not penetrate to the pith and there should be no internal staining or streaking in the tissue that leads away from the disbudding wound.

Green Potted Vines

In addition to the above criteria, green potted vines should also conform to the following standards:

1. Shoots and roots should be strong and well developed. Roots should be evenly spaced.
2. There should be no signs of powdery or downy mildew, *Botrytis* spp. or *Phomopsis* spp.
3. There should be no signs of invertebrate pests such as phylloxera, mealy bugs, parasitic nematodes, or scale.
4. The vines should not show signs of water stress such as wilting.
5. The potting medium should be soilless with a pH of 6-6.5.
6. The potting medium should be moist, not dry or soggy.

Part 3: Guidelines for the Management of Rootstock and *Vitis vinifera* Mother Vines for the Production of Quality Cuttings

Introduction

Mother vine source blocks are the very foundation of the grape and wine industries.

Healthy vigorous cuttings of known variety and clone that propagate readily and are able to withstand the rigours of the propagation process are essential to the production of healthy vigorous nursery vines.

Rootstock mother vine blocks

Characteristics of quality mother vine source blocks

Mother vine source blocks should:

1. Be registered with the relevant authority in each Country, state or district.
2. Be of known variety, clone and provenance.
3. Be inspected at least once a year during the growing season for external signs of pests and diseases that can be transmitted in propagation and for off types.
4. Be managed in such a way as to reduce the chances of infection with endogenous pathogens including phytoplasmas, crown gall and trunk disease pathogens.
5. Have disease status confirmed by random annual sampling and laboratory analysis, for the presence of endogenous pathogens including phytoplasmas, crown gall and trunk disease pathogens.
6. Be managed in a manner that reduces the chances of the accidental introduction of pests, diseases and weeds to the vineyard. This may include, but is not confined to, restrictions on the entry of people, plants and machinery, the planting of wind breaks and other environmental management practices, treatment of irrigation water and any other measures deemed appropriate to the situation and control of invertebrate vectors.

Establishment of rootstock mother vine blocks

1. A site should be chosen that will conform to the requirements of the registering authorities that have governance over the area where the site is located.
2. Where practicable, mother vine sites that have not formerly been used for growing vines are preferred.
3. Sites should be secure and located in areas where the climate and soils are suited to the growth of healthy mother vines of moderate vigour.
4. Where practicable, mother vine blocks should be situated away from potential sources of serious pests and diseases.
5. Mother vines sites should have an assured water supply adequate for the growth of quality cuttings, particularly in times of drought.
6. Sites should be free of serious weeds, pests, diseases, parasitic nematodes and vermin, particularly those that have a serious impact on vine health, or are subject to quarantine regulations.
7. By virtue of location, slope and soil type be readily accessible to vehicles and machinery.
8. Nursery vines for planting in mother vine blocks should conform to the standards described in part 2 of this document; 'Quality criteria for nursery vines ready for planting in vineyards'.

Management of established mother vine blocks

Training and trellising

1. The vigorous habit of most rootstock varieties and economic constraints mean that the shoots of mother vines are not normally supported by trellising, but are allowed to sprawl across the ground. This predisposes cuttings to contamination by soil borne pathogens and where possible, the use of an appropriate form of trellising to keep the canes off the soil surface is desirable if economics permit. Appropriate organic mulches may also be useful.
2. It is recommended that the number of shoots per vine be restricted to that which will produce the maximum number of fully lignified canes of the desired diameter (7-12 mm) and internode length (dependent on variety).

Soil and water management

Water

1. The quality of irrigation water should be monitored regularly and be such that suspended solids do not block dripper or sprinkler outlets and water borne pathogens, particularly nematodes cannot be detected.
2. Irrigation water should be applied throughout the season as appropriate in sufficient quantities and at appropriate intervals to ensure that the mother vines are not subjected to water stress and canes are able to fully lignify without encouraging excessively rank and weak growth and meet calibre specifications for the variety. This can be achieved by using soil moisture monitoring devices and visual observation of the vines and evaluating soil moisture in samples dug from the root zone.
3. Drip irrigation is preferable to the use of overhead sprinklers to reduce the chances of pathogens being spread by water splash.

NB: Irrigation schedules for mother vines will be different to irrigation schedules for vines grown for wine grapes because the end product is wood, not grapes. Mother vines should be watered throughout the season, particularly after mid summer when water to vines for wine grapes is often restricted, to ensure proper carbohydrate accumulation in the canes and good lignification of the canes.

Soil

1. The soil should be tested regularly (every 2-3 years) to ensure that the pH remains within the range of 5.5-7.5 and ameliorants such as lime or gypsum applied as appropriate. Petiole tests may also be useful.
2. The soil should be maintained in a manner that maintains organic matter and supports beneficial soil biota. The use of mulches or cover crops may be helpful where practicable.
3. The soil surface should be managed in a manner that reduces windblown dust and mud splash during irrigation and rain events. Organic mulches not contaminated by diseases, pests and weeds may be helpful in this respect, particularly in source blocks where the mother vines are trellised.

4. Appropriate nutrients based on the results of annual soil or petiole tests should be applied to the vines. It should be noted that cutting production requires a different fertilizer regime to grape production. In particular, adequate calcium and potassium is required for wood production and excessive amounts of nitrogen that will result in rank growth and weak cuttings that fail in propagation should be avoided.

Pest and disease management

1. A regular cultural and spray program using appropriate registered pesticides is essential to control problem weeds and pests and diseases such as botrytis, powdery mildew, downy mildew, mealy bugs and scale.

Part 4: Guidelines for the Production of Quality Nursery Vines

Introduction

Grapevine nurseries are vital to the establishment of healthy, productive and sustainable vineyards. The quality of nursery vines planted in a vineyard forms the foundation of vine health for the life of the vineyard.

Nursery sanitation

Nursery sanitation is critical to the production of quality vines. For details of appropriate sanitary measures, nurseries should refer to the text Plant *Propagation Principles and Practices* Current edition, by H.T. Hartmann, D.E. Kester and F.T. Davies; Prentice Hall International Editions. Nursery water must be of potable quality. However, irrigation water for field nurseries can be of lesser quality provided that it is free of colloidal material, inorganic contaminants such as salt and pesticides and pathogenic nematode, bacteria and fungi.

Source of cuttings

Cuttings of both rootstock and scion varieties should be obtained from registered mother vine blocks that are inspected and tested regularly for pests and diseases and off types.

NB: It should be noted that regardless of how well they are managed, the manner of cutting production predisposes mother vines to infection by trunk disease organisms.

Infected cuttings have no visible internal or external symptoms. Visible symptoms are not apparent for several months after the infective agents (spores or mycelium) move into the tissue of the current season's canes. Therefore, it should be assumed that ALL cuttings have some level of infection. Hot water treatment is the only control currently known to be effective. The application of fungicides does not effectively control internal pathogens.

Handling cuttings

On arriving at the nursery the cuttings should be checked to ensure that they:

1 Are correctly labelled and accompanied by electronic and/or hard copy documents and/or reference numbers that enable trace back through to the source blocks of origin.
2. Conform to the standards described in parts 1 and 3 of this document.
3. Processed immediately or stored in a clean cool room at 1-2^{o}C in packaging that allows air to reach the cuttings without danger of dehydration, but without free water.

Processing cuttings

1. Before propagation both rootstock and scion cuttings should be graded for size and any cuttings that are not fully lignified, out of size (<7 mm or >12 mm in diameter just above the top bud), damaged or diseased should be destroyed.
2. Every effort should be made to prevent dehydration of cuttings. This includes prompt processing, covering cuttings with clean damp cloth, keeping them away from direct sunlight and heaters and keeping them out of the wind.
3. Cuttings **should not be soaked in water** as even clean treated water will enable bark inhabiting microorganisms to contaminate the cut ends and disbudding wounds. Soaking can cause cuttings to become fermentative and does not compensate for dehydration.

Hot Water Treatment

1. Hot water treatment is an effective control for a range of pests and pathogens, including trunk disease pathogens that are likely to be present in cuttings entering the nursery (and/or finished nursery vines just prior to planting).

2. The standard hot water treatment is 50^{o}C for 30 min. However HWT protocols vary somewhat in different climates (cutting/vine and pathogen tolerance vary between warmer and cooler climates) and nurseries are advised to seek advice from local scientists before proceeding with any particular protocol.
3. HWT plant and equipment should be designed and function in a manner that enables them to function efficiently and be easily emptied and cleaned.
4. HWT tanks should be fitted with accurately calibrated temperature monitoring probes placed at the top, bottom and middle of the tank during operation.
5. HWT plant and equipment must be checked annually by the relevant accrediting authority to ensure that that it is operating to specifications and hot and cold spots do not occur during treatment.
6. Hot water treatment must be monitored by a competent trained person.
7. The date, time, duration and temperature of each treatment must be recorded from a minimum of 3 zones in the tank (top, middle and bottom), along with the batch numbers of the treated material using electronic data logging equipment.
8. Cuttings and vines should be allowed to come to ambient temperature before HWT. This can take 8-12 hours for large volumes of material. Material should not be treated straight from the cool room or left to warm to the point where it begins to emerge from dormancy (approximately 24 hr depending on temperature and variety).
9. All water used in HWT plants including cool down tanks must be sanitised and changed at least daily to avoid the build up of heat tolerant pathogens.
10. The standard practice of rapidly cooling hot water treated cuttings in cold water is under investigation. There is evidence to suggest that water cooling introduces pathogenic fungi and bacteria into the hot water treated cuttings. Canes can be cooled effectively by quickly unpacking the treatment baskets and allowing cuttings to air cool in a clean air environment away from mud, dust and wind. This reduces the risk of recontamination by cool down water.
11. It is essential to process hot water treated cuttings soon after treatment. If cuttings are to be stored after HWT they must be allowed to recover for 24 hours before being placed back in cold storage.

12. Cuttings must not be stored when obviously wet. This promotes the growth of heat tolerant fungi that are not normally pathogenic, but may damage cuttings in the low light, low oxygen and high moisture environment of cold storage.
13. Hot water treated cuttings must not be stored with free water in the packaging.
14. Packaging should be adequately ventilated to prevent oxygen deprivation and fermentation without exposing the cuttings to dehydration.
15. Cuttings should not be stored with, or come into contact with untreated cuttings or finished vines.

Bench Grafting

1. Bench grafting should be done in a room or shed designated for the purpose that is clean and free of dust and dirt.
2. The room should not be open to rain and wind-blown dust or birds and other vermin.
3. The grafting room should be cleaned at the end of each working day.
4. Floors should not be swept while grafting is being done as this increases contamination from raised dust.
5. All benches, grafting machines and tools should be cleaned at every meal break during the day and sanitised with appropriate disinfectants.
6. All containers for storing cuttings and grafted vines must be treated with disinfectant or steam pasteurized before use.
7. Cuttings and/or buds must not be soaked during the grafting process.
8. All workers should wear clean aprons or overalls every day.
9. If gloves are worn they must be changed at every meal break.
10. Workers must wash their hands at every meal break.
11. Any cuttings or buds with dead or brown tissue should be discarded and destroyed.
12. Grafting ties, clips etc. should be new and stored away from dust and other contaminants.
13. Grafts should be well matched to ensure complete healing. Incompletely healed grafts are vulnerable to post grafting infection.

Callusing

1. Callusing rooms should be cleaned regularly to prevent the build up of pathogens such as *Botrytis* spp. Floors should be mopped rather than swept to avoid raising dust that could introduce contaminants to the callusing boxes. Spraying water to clean floors and walls should also be avoided as pathogens can be spread by water splash.
2. Callusing rooms should be designed to prevent hot or cold spots.
3. Callus box packing density must not too high. High density packing will create a high temperature and low oxygen environment favouring the development of pathogens. The temperature inside callusing boxes can become hot very quickly from a build up of metabolic heat.
4. All callusing media must be new and free of microbial and abiotic contaminants and should be stored in a clean place away from agrochemicals, dust and wind.
5. The callusing media must be able to retain moisture but should not be wet.
6. Callusing temperature should not be too high. Callusing at higher temperatures (>27^{o}C) may result in the proliferation of weak tissue that does not form a good union.
7. Care should be taken to prevent the outbreak of fungal pathogens. It may be useful to briefly dip grafted cuttings in a fungicide before packing them in the callusing medium.
8. Dipping the graft union in a ***thin*** layer of clean grafting wax may help to protect the graft union from dehydration and infection during callusing. A heavy coating of wax may result in undesirable anaerobic conditions around the graft union and scion.
9. Cuttings should be removed from the callusing medium as soon as sufficient callus has formed to join the cut edges together. Over callusing is undesirable and may impede the formation of new xylem and phloem across the graft. Avoid damaging callus tissue during handling.

Growing on

1. Callused cuttings and grafted vines are very susceptible to environmental stress.

2. It may be beneficial to harden callused cuttings by removing the top few centimetres of callusing medium and holding the callusing boxes in a protected but cooler environment that is well illuminated for several days before planting out or potting.
3. The tops of the callused cuttings should be dipped in a thin layer of wax to protect the bud and graft union if this was not done prior to callusing.
4. For potted vines the potting medium should be soilless and from a specialist supplier of potting mixes to nurseries and should comply with prescribed sanitary and horticultural standards.
5. The potting medium should be free draining, but retain enough moisture to supply the needs of the developing vine.
6. Field nurseries should have a light soil that is free draining and easy to work.
7. Nursery sites should be rotated to prevent the build up of nematodes and soil borne pathogens such as black-foot pathogens. Brassica crops such as mustard, used appropriately are useful bio-fumigants to include in a nursery rotation.
8. Weeds compete with the vines and may be hosts to pests and pathogens and should be controlled before and after planting.
9. Field nurseries and potted vine should be protected from hot and cold winds.
10. Field nurseries and potted vines require smaller amounts of irrigation water at frequent intervals until the vine have an established root system.
11. Potted vines and field nurseries should be treated regularly for pests and diseases such as mealy bugs, *Botrytis* spp., powdery mildew and downy mildew.

Lifting and handling finished vines

1. At the end of the season finished vines should be carefully lifted from the field nursery and trimmed appropriately.
2. To avoid cross contamination, processing of finished vines should not occur in the same area as grafting.
3. Finished vines should be graded and any damaged, diseased or second quality vines discarded and destroyed.
4. Vines should be checked for trunk diseases before sale by dissecting a few sample plants chosen randomly from each batch (5-10 per 1000). Cut the rootstock, the scion and the graft union and look for dark staining and/or spotting in the tissue. Any

tissue discolouration in the wood extending away from wound sites indicates that the vines have probably been infected with one or more of the fungi that cause Young Vine Decline and should not be sold.

5. Finished vines offered for sale should conform to the specifications outlined in part 2 of this document.
6. Finished vines (both potted and bare rooted) should be free of weeds and debris.
7. Finished vines should be labelled and packaged in new and clean packaging that allows enough air flow to prevent fermentation, but not so much that the vines become dehydrated.
8. Finished vines should be stored in a cool room at 1-2^{o}C until despatch.
9. If hot water treatment of finished vines is required, the vines should be removed from the cool room at least 8-12 hours before treatment (see above). Vine roots should not be trimmed in the period prior to HWT.
10. Vines should not be returned to the cool room after hot water treatment. They must be allowed to recover for 24 hours before packaging and despatch and planted as soon as possible after hot water treatment.
11. It is preferable that finished vines not be hot water treated and despatched until the customer is prepared for planting; the irrigation installed if necessary, contractor booked and soil preparation completed.
12. Customers should be advised in advance of shipping dates.
13. Vine should not be transported with materials such as agrochemicals and fresh produce that could compromise their quality.
14. The transport company should subscribe to a quality assurance scheme.
15. Transport must be prompt and without delays in storage depots.

Part 5: Criteria for Selection and Handling of Grapevine Planting Material

Introduction

Quality grapevine planting material is fundamental to the development of healthy, long lived and sustainable vineyards that produce the maximum yield of grapes of the highest quality with a minimum of inputs.

The criteria listed here are provided as a general guide to the quality of planting material. When choosing grapevine varieties, clones and rootstocks growers are advised to seek advice from a wide range of sources including consultants, scientists, extension staff, nurseries and neighbouring grape producers to determine the most appropriate varieties, clones and rootstocks for the site.

The quality of nursery vines for planting in vineyards should conform to the criteria described in part 2 of this document 'Quality Criteria for Rooted Nursery Vines Ready for Planting in Vineyards'.

It is strongly recommended that growers or their agents visit the supplying nursery before placing an order and that the material be inspected prior to despatch to ensure that it conforms to the agreed standards.

Nursery Selection

1. Nurseries should have an appropriate quality assurance certification, and/or be certified by an appropriate organization such as a government regulatory body or a nursery industry organization.
2. Propagating material (cuttings) should be obtained from registered source blocks of known disease status.
3. Nurseries should have a high standard of general hygiene. Sheds, work surfaces, tools and equipment should be free of dust, dirt and vermin, including birds.
4. All water used in propagation should be treated (filtered and chlorinated, UV treated etc.) to remove water borne contaminants.

Working with the nursery

1. Vines should be ordered 12-18 months in advance to enable nurseries to order cuttings and ensure supply. Production of dormant bare rooted vines takes twelve months and green potted vines up to 6 months from the time cuttings are collected.
2. Be specific about the type of planting material that is required. Vines are normally supplied as dormant bare rooted plants available in late winter, but some nurseries also produce green potted vines in biodegradable pots that are supplied in late spring or early summer. These vines are planted pot and all.
3. Maintain contact with the nursery, but do not pester them. This will help to ensure early notification if the nursery has any unforseen difficulties with supply.
4. Negotiate with the nursery regarding delivery and ensure that preparations have been made to care for the vines on arrival.

Pre planting care of vines

1. Pre planting care is critical to maintaining the quality of the vines.
2. The vineyard must be ready for planting pre dispatch. Irrigation infrastructure, weed control and cultivation all finished. Arrangements should be in place to ensure that vines are planted immediately on arrival at the planting site.
3. All vines should be inspected on arrival to ensure that they are the correct variety, clone and rootstock and they conform to the quality standards outlined in part 2 of this document; 'Quality Criteria for Rooted Nursery Vines Ready for Planting in Vineyards' and are accompanied by the appropriate documents.
4. Packaged dormant bare rooted vines should have a pleasant earthy aroma and should not smell of fermentation (winey aromas).
5. Dissect a random sample of vines from each batch. Cut the rootstock, the scion and the graft union and look for dark staining and/or spotting in the tissue. Any tissue discolouration in the wood indicates that the vines have probably been infected with one or more of the fungi that cause Young Vine Decline and should not be accepted.
6. Check all graft unions for strength. The graft union of a dormant vine should not break under moderate pressure from the thumb. Be careful when checking the

graft unions of green potted vines as they are not yet fully hardened, however they should be complete and be able to withstand some moderate pressure.

7. Never leave packages of vines lying around in sheds.
8. If dormant bare rooted vines must be stored they should be 'heeled in' by placing the bundles upright in a trench dug for the purpose and the roots covered with loose soil, sand or well rotted sawdust kept moist but not wet.
9. Cold storage of nursery vines is not recommended. However, if there is no alternative vines can be stored for short periods at 1-2^{o}C in clean cool rooms. Packaging should conform to the criteria described in part 4 of this document; 'Guidelines for the Production of Quality Nursery Vines'.
10. **Under no circumstances** should vines be stored with fruit or vegetables that emit ethylene or have been treated with ethylene, or have been treated with sprouting inhibitors. These substances penetrate packaging and seriously damage vines.
11. Green potted vines should be placed in dappled shade out of the wind and watered frequently to ensure that the potting mix does not dry out. If potting mixes are allowed to dry out they become hydrophobic and are very difficult to re wet. Over watering is also detrimental.

Hot water treatment

1. If nursery vines are to be hot water treated before delivery the HWT plant should be calibrated by an independent authority annually and the nursery should employ a trained operator and the process should conform to the description outlined in above.
2. **For preference, hot water treated vines should not be placed in cold storage, but should be planted or 'heeled in' by placing the bundles upright in a shallow trench and loosely covering the roots with moist soil or sand if planting is unavoidably delayed.**
3. **Hot water treated vines should not be re-packaged for despatch within 12 hours of treatment to enable recovery from the heat shock.**

Planting

1. Newly planted vines have small root systems. Consequently they require small frequent irrigations gradually increasing in volume and decreasing in frequency as the vines become established.
2. Vines, particularly the roots, should not be allowed to dry out during planting. However, standing vines with freshly trimmed roots in a bucket of water is detrimental, spreads disease and should be avoided. It is better to cover bundles with a clean damp cloth.
3. Green potted vines should be planted with the rim of the pot 50mm below soil level. This prevents the pot acting as a wick drawing water away from the root zone of the vine.
4. It is usual to trim the roots and shoots of dormant bare rooted vines just prior to planting. Shoots are normally trimmed to 2 buds and roots to the length of a closed fist (80-100 mm). Trimming the roots stimulates new root growth and facilitates planting the vines with straight downward pointing roots. This prevents the problem of 'J' or 'umbrella' roots where the roots are bent upwards. Vines with 'J' roots fail to establish and will die soon after planting.
5. **Never return vines to cold storage once they have been removed for trimming. Returning vines to cold storage after trimming results in vines failing after planting.**

Part 6: Further reading

The references listed below are a representative sample of literature the reader may find useful. However, it is not exhaustive and does not include every reference on grapevine propagation and trunk diseases. Readers are advised to seek out other references as are appropriate to their situation.

Text books

Baker, K.F. 1957. The *UC system for producing healthy container grown plants*. University of California Experimental Station Service manual 23.

Hartmann, H. T., Kester, D. E., Davies, F. E., and Geneve, R. 2001. Hartmann and Kester's Plant Propagation: Principles and Practices. 7th ed. Prentice-Hall, Englewood Cliffs, NJ.

Hidalgo, L. 2002. Tratado de Viticultura General. Ed. Mundi-Prensa, Madrid, Spain.

Jackson, R. S. 2008. Wine Science Principles and Applications, Academic Press, Saint Louis, USA.

Krake, L. R., Steele Scott, N., Rezaian, M.A. & Taylor, R. H. 1999, *Graft-transmitted diseases of grapevines,* CSIRO Publishing, Collingwood, Victoria.

Nicholas, P. R., Chapman, A. P., and Cirami, R. M. 2001. Grapevine Propagation. Pages 1-22 in: Viticulture, Vol. 2, Practices. B. G. Coombe and P. R. Dry, eds. Winetitles, Adelaide, Australia.

Weaver, R. J. 1976. Grape Growing, John Wiley & Sons, New York.

Winkler, A. J., Cook, J. A., Kliewer, W. M., and Lider, L. A. 1974. General Viticulture, University of California Press, Berkeley.

Peer reviewed articles

Alaniz, S., Abad-Campos, P., García-Jiménez, J., and Armengol, J. 2011. Evaluation of fungicides to control *Cylindrocarpon liriodendri* and *Cylindrocarpon macrodidymum in vitro*,

and their effect during the rooting phase in the grapevine propagation process. Crop Prot. 30:489-494.

Aroca, A., Gramaje, D., Armengol, J., García-Jiménez, J., and Raposo, R. 2010. Evaluation of grapevine nursery process as a source of *Phaeoacremonium* spp. and *Phaeomoniella chlamydospora* and occurrence of trunk disease pathogens in rootstock mother vines in Spain. Eur. J. Plant Pathol. 126:165-174.

Caudwell, A., Larrue, J., Boudon-Padieu, E., and Mclean, G. D. 1997. Flavescence dorée elimination from dormant wood of grapevines by hot-water treatment. Aust. J. Grape Wine R. 3:21-25.

Fourie, P. H., and Halleen, F. 2004a. Proactive control of Petri disease of grapevine through treatment of propagation material. Plant Dis. 88:1241- 1245.

Fourie, P. H., and Halleen, F. 2002. Investigation on the occurrence of *Phaeomoniella chlamydospora* in canes of rootstock mother vines. Aust. Plant Pathol. 31:425-426.

Fourie, P. H., and Halleen, F. 2006. Chemical and biological protection of grapevine propagation material from trunk disease pathogens. Eur. J. Plant Pathol. 116:255-265.

Gramaje, D., Armengol, J., Salazar, D., López-Cortés, I., and García-Jiménez, J. 2009a. Effect of hot-water treatments above 50°C on grapevine viability and survival of Petri disease pathogens. Crop Prot. 28:280-285.

Gramaje, D., Aroca, A., Raposo, R., García-Jiménez, J., and Armengol, J. 2009b. Evaluation of fungicides to control Petri disease pathogens in the grapevine propagation process. Crop Prot. 28:1091-1097.

Gramaje, D,. and Armengol, J. 2011. Fungal trunk pathogens in the grapevine propagation process: potential inoculum sources, detection, identification, and management strategies. Plant Disease 95(9):1040-1055.

Halleen, F., Fourie, P. H., and Crous, P. W. 2006. A review of black foot disease of grapevine. Phytopathol. Mediterr. 45S:55-67.

Halleen, F., Fourie, P. H., and Crous, P. W. 2007. Control of black foot disease in grapevine nurseries. Plant Pathol. 56:637-645.

Lear, B., and Lider, L.A. 1959. Eradication of root-knot nematodes from grapevine rootings by hot water. Plant Disease Rep. 14(3):314-317.

Morton, L. 2000. Viticulture and grapevine declines: Lessons of black goo. Phytopathol. Mediterr. 39:59-67.

Mostert, L., Groenewald, J. Z., Summerbell, R. C., Gams, W., and Crous, P. W. 2006. Taxonomy and pathology of *Togninia* (*Diaporthales*) and its *Phaeoacremonium* anamorphs. Stud. Mycol. 54:1-115.

Mugnai, L, Graniti, A., and Surico, G. 1999. Esca (black measles) and brown wood-streaking: two old and elusive diseases of grapevines. Plant Dis. 83:404-416.

Ophel, K., Nicholas, P. R., Magarey, P. A., and Bass, A. W. 1990. Hot water treatment of dormant grape cuttings reduces crown gall incidence in a field nursery. Am. J. Enol. Vitic. 41:325-329.

Orffer, C.J. 1977, 'Hot-water treatment of vine propagating material- urgently necessary in RSA', *The Deciduous Fruit Grower*, July 1977, 224-231.

Orffer, C.J. and Goussard, P.G. 1980. 'Effect of hot-water treatments on budburst and rooting of grapevine cuttings'. Vitis 19:1-3.

Orffer, C.J. Goussard, P.G. Bosman, D.C. Morkel, D.C., and Wiese, J.J. 1979, 'The effect of hot-water treatment and growth regulators on budburst and rooting of cuttings of the grapevine rootstock cultivar USVIT 2-1'. The Deciduous Fruit Grower, October 1979, 340-344.

Rooney, S. N., and Gubler, W. D. 2001. Effect of hot water treatments on eradication of *Phaeomoniella chlamydospora* and *Phaeoacremonium inflatipes* from dormant grapevine wood. Phytopathol. Mediterr. 40S:467- 472.

Samish, R.M., and Spiegel, P. 1957. The influence of the nutrition of the mother vine on the rooting of cuttings. Publication of the Agricultural Research Station, Rehovot. 1957 Series, no. 207-E:93-100.

Retief, E., McLeod, A., and Fourie, P. H. 2006. Potential inoculum sources of *Phaeomoniella chlamydospora* in South African grapevine nurseries. Eur. J. Plant Pathol. 115:331-339.

Ridgway, H. J., Sleight, B. E., and Steward, A. 2002. Molecular evidence for the presence of *Phaeomoniella chlamydospora* in New Zealand nurseries, and its detection in rootstock mothervines using species-specific PCR. Aust. Plant Pathol. 31:267-271.

Úrbez-Torres, J. R. 2011. The status of Botryosphaeriaceae species infecting grapevines. Phytopathol. Mediterr. 50:S5-S45.

Waite, H., and May, P. 2005. The effects of hot water treatment, hydration and order of nursery operations on cuttings of *Vitis vinifera* cultivars. Phytopathol. Mediterr. 44:144-152.

Waite, H., and Morton, L. 2007. Hot water treatment, trunk diseases and other critical factors in the production of high-quality grapevine planting material. Phytopathol. Mediterr. 46:5-17.

Wample, R. 1993, 'Influence of pre- and post-treatment storage on budbreak of hot water treated cuttings of cabernet sauvignon'. Am. J. Enol. Vitic. 44(2).

Wample, R. 1997, 'Influence of pre- and post-treatment storage on rooting of hot-water-treated cuttings of cabernet sauvignon'. Am. J. Enol. Vitic. 48(2).

Wample, R., Bary, A., and Burr, T.J. 1991. 'Heat tolerance of dormant *Vitis vinifera* cittings', Am. J. Enol. Vitic. 42(1):67-72.

Zanzotto, A., Autiero, F., Bellotto, D., Dal Cortivo, G., Lucchetta, G., and Borgo, M. 2007. Occurrence of *Phaeoacremonium* spp. and *Phaeomoniella chlamydospora* in grape propagation materials and young grapevines. Eur. J. Plant Pathol. 119:183-192.

Articles from grower magazines

Anonymous, 2005. La pépinière viticole française: objective qualité. Viniflhor, FranceAgriMer. http://www.onivins.fr.

Hunter, J. J., Volschenk, C. G., Le Roux, D. J., Fouché, G. W., and Adams, L. 2004. Plant Material Quality, a compilation of research. Research Reports, ARC Infruitec-Nietvoorbij, Stellenbosch, South Africa.

Larignon, P., Coarer, M., Larbre, C., Girardon, K., Viguès, V., and Yobregat, O., 2009. Identification sur le matériel végétal des sources d'inoculum des champignons associés aux maladies du bois. Phytoma, 622-623, 46-48.

Larignon, P., Fontaine, F., Farine, S., Clément, C., and Berstch, C. 2009. Esca et Black Dead Arm : deux acteurs majeurs des maladies du bois chez la Vigne. CR Biologies 332 :765-783.

Vigues, V., Yobregat, O., Barthelemy, B., Dias, F., Coarer, M., Girardon, K., Berud, F., Muller, M., and Larignon P., 2010. Maladies du bois de la vigne, les prévenir en pépinières. Phytoma. 638, 27-29.

Waite, H. 2006. Who is responsible for the quality of planting material in Australian vineyards? Looking to the future. Aust. New Zeal. Grape. Wine. 507:40-42.

Waite, H. 2010. Trunk diseases and vine failure: The costs of poor quality propagating and planting material. Aust. New Zeal. Grape. Wine. 555:21-22.

Waite, H. 2010. Quality matters: Good planting material is an important part of the vine health system. National Wine and Grape Industry Centre, Locked Bag 588, Wagga Wagga, NSW, 2678 Australia. http://www.csu.edu.au/research/nwgic/Docs/svhfd/h-waite-quality-matters.

Waite, H., Cole, M., Jaudzems, G., and Faragher, J. 2004. Recent advances in grapevine propagation research. Aust. New Zeal. Grape. Wine. 485:39-40.

Certification schemes

OEPP/EPPO, 2008. Certification scheme. No. PM 4/8 (2): Pathogen-tested material of grapevine varieties and rootstocks. Bull. OEPP/EPPO Bull. 38:422-429.