Standardised protocols for conducting grapevine improvement trials in Australia



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Edited by P. Nicholas

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1. Introduction

More than 250 vine improvement trials to select suitable clones and rootstocks for particular regions have been conducted in Australia over the past 30 years – particularly in South Australia and Victoria. Clonal trials involve the selection of candidate clones from existing vineyards and the comparison of these in trials with clones selected in similar programs in other states of Australia and overseas. The most suitable clones for each region are then multiplied for release into vine improvement schemes and made available to the grape industry.

Rootstocks vary in characteristics such as the vigour they impart to the scion, their tolerance to phylloxera, nematodes, acid soil, lime, salinity, drought and waterlogging and in the uptake of nutrients such as potassium which can affect juice pH. Rootstock trials are conducted to select the most suitable rootstocks for particular scions when grown in different environmental situations including variations of soil type and climate.

However, it may be difficult to compare data from different trials if they have been designed differently and standard evaluation methods have not been used. It may also be difficult to relate trial results to other sites if the environment at the trial site has not been adequately defined. A workshop was sponsored by the Grape and Wine Research and Development Corporation to encourage greater coordination of trial work across Australia. Representatives from 25 agencies and industry Australia-wide attended. Researchers were nominated to develop standardised methodology for use in vine improvement programs in Australia including the selection of candidate clones, and trial design, measurement and site definition.

Benefits were seen as:

- Greater coordination of vine improvement research across Australia and a rationalisation of the number of trials assessed, which will allow more efficient use of limited research resources.
- The extraction of more information from each trial and greater ability to detect differences between genotypes.
- The ability to more easily compare data from different trial sites, and relate information to other sites without trials which have similar environmental conditions.
- Better matching of clones to particular regions.
- Better selection of rootstocks for particular scions, soil types and soil conditions (including seasonal soil moisture regimes) to give the best balance between yield and fruit quality.

This report proposes guidelines for future work with the aim that it will increase the effectiveness of vine improvement research, resulting in the selection of superior planting material and ultimately the production of better quality grapes in each region.

2. Selection of candidate clones for trials

2.1 Sources of clones

Candidate clones which are to be compared in trials may come from a number of sources:

- Local selections – vines selected from vineyards of proven performance and quality by marking one or several vines, which appear to have characteristics considered desirable (e.g. loose bunches or smaller berries). Selected vines should be observed over 2 or more years just prior to harvest. They should also be observed for the presence of virus diseases – particularly in Autumn for leafroll virus. Often very old blocks are studied because vines from these are more likely to be free of debilitating viruses.
- Clones freed of viruses e.g. by meristem tip culture or heat treatment.
- Clones imported from overseas selection programs.
- Breeding programs.

2.2 Virus status

2.2.1 Viruses important in Australia

Candidates should be free of the following viruses:

- Leafroll viruses – nine have been detected. GLRaV-1 and GLRaV-3 are the most common. Infection can cause yield reductions of up to 50% in some varieties. Leafroll can also affect grape quality. Grapes may have a lower sugar content and red berries may be lighter in colour with lower anthocyanins. GLRaV-2 can cause graft incompatibility. GLRaV-3 (and probably GLRaV-1) can be spread by mealybugs.
- Rugose wood complex viruses – four different types can be distinguished by biological indexing; Rupestris stem pitting, Kober stem grooving, corky bark and LN33 stem grooving. These syndromes are difficult to distinguish in the field. They mainly cause problems with grafted vines. Symptoms include swelling above the graft, and wood with pits or grooves (seen after bark is removed). Budburst may be delayed. Vines may decline and even die – this varies with the stock/scion/virus interaction. Water stress and the combination of rugose wood and leafroll viruses increase the problems. Kober stem grooving and corky bark can be spread by mealybugs.
- Fleck – no field symptoms of fleck virus are seen on *V. vinifera* and most rootstocks. The combination of fleck and leafroll may reduce graft take.
- Fanleaf – symptoms include fan-shaped leaves and distorted canes or yellow mosaic symptoms, smaller bunches, shot berries and greatly reduced yield. Fanleaf does occur in Australia, but it is not as important here as in Europe, because the nematode vector *Xiphinema index* is not present in most regions.

2.2.2 Virus testing methods

Methods used to detect viruses (Table 2-1) are:

- Biological indexing – here candidate clones are budded onto an indicator variety (or vice versa) and planted in a field nursery. Assessment takes 2-3 years. Researchers at most overseas institutes consider that biological indexing is still essential for the certification of grapevines.
- ELISA – a serological method which is cheap, easy and widely used.
- RT-PCR – a more recently developed but expensive molecular method, which is more sensitive than ELISA.

Preliminary screening of clones can be achieved by RT-PCR and ELISA testing. Biological indexing should then be conducted on the remaining clones. Use of the three testing methods provides a more reliable indication of virus status. Note that quarantine regulations must be observed when submitting samples for testing (the local state agriculture agency should be contacted for information on these regulations).

Table 2-1 Virus detection methods commonly used in Australia

Virus diseases	Indexing variety	ELISA test	RT-PCR test
Fan leaf			
Grapevine fanleaf virus	Rupestris St George	GFLV	GFLV
Leafroll			
Grapevine leafroll associated viruses	Cabernet Franc	GLRaV-1, GLRaV-3	GLRaV-1, GLRaV-2, GLRaV-2RG, GLRaV-3, GLRaV-4, GLRaV-5, GLRaV-9
Rugose wood complex			
Rupestris stem pitting	Rupestris St George		RSPaV
Kober stem grooving	5BB Kober	GVA	GVA
Grapevine corky-bark	LN33		GVB
LN33 stem grooving	LN33		
Fleck			
Grapevine fleck virus	Rupestris St George	GFkV	GFkV-A, GFkV-B

2.3 Clonal characteristics

The basis of clonal selection and multiplication is that the characteristics of the plant are carried through to the progeny through vegetative propagation. When vines are selected for assessment in trials, the characteristic being selected for e.g. loose bunches or small berry size, must be observed to check that it is genetically based and not a one-off aberration due to a climatic or local phenomenon. It is essential to observe vines over 2 or more years to ensure the characteristic remains present. In some cases the selection characteristic is limited to one shoot, or only part of the vine and the selected area must be clearly tagged, so that cuttings are only taken from this part of the vine for propagation. Methods of measuring selected characteristics are given in Section 6. If it is envisaged that a selection may be registered for Plant Variety Rights, then detailed measurements differentiating it from other clones is required, particularly during the comparative trial stage.

2.4 Germplasm collections

2.4.1 Overseas collections

Clones are held in two different types of grapevine germplasm collections in most countries:

- Genetic resource collections – here a large number of varieties are held to preserve the varieties not used commercially and also to retain genetic diversity of varieties which are used commercially. The largest of these, at Vassal (near Montpellier in France) has 7,200 clones which include 3,200 varieties. These collections are also useful for ampelography and breeding. Although many clones have viruses which can spread, virus status is not really an issue
- Nuclear collections of elite clones distributed in vine improvement schemes – here clones must be certified free of important viruses by biological indexing, before they can be planted in the collection and each vine is periodically retested for viruses e.g. retesting is done every three years by ELISA at Davis in California. Holding clones in nuclear collections greatly reduces the chance of spread of virus by insect vectors from vine to vine.

2.4.2 Australian collections

- Genetic resource collections – major genetic resource collections are held by CSIRO at Merbein and SARDI at Nuriootpa.
- Nuclear collections – a project to select 300 clones to plant in new nuclear collections in Australia has being funded by the Grape and Wine Research and Development Corporation. Clones are being selected using RT-PCR, ELISA and biological indexing from existing genetic resource collections and from programs to eliminate virus by meristem tip culture. Clonal characteristics are being considered in the selection process.

2.5 Sources of propagation material for trials

Candidates for clonal or rootstock trials should ideally be propagated from material held in a nuclear collection, but if material is not available, then it should be obtained from pre-multiplication rows (which have been established to provide material for vine improvement associations to propagate source blocks). Material taken from source blocks is usually not considered sufficiently reliable for use in establishing clonal or rootstock trials. If the desired candidates are newly selected and have not undergone the stringent testing procedure for establishment in a nuclear collection, they should at least be tested by RT-PCR for viruses for two years prior to planting in a trial.

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3. Trial design, management and analysis

3.1 General considerations

3.1.1 Spatial variation

Between regions

Large differences in environmental conditions exist between the grapegrowing areas of Australia, primarily due to different climate, topography and soil. These differences in turn affect other factors such as susceptibility to diseases and pests. There are also large variations in management practices e.g. canopy management and the application of irrigations. As these differences between regions are substantial, the resulting genotype by environment interactions make the interpretation of statistical analyses of trial data from different regions difficult (unless trials are designed to specifically investigate these differences).

Within regions

Sites chosen within a region also exhibit spatial variation e.g. due to varying topography or soil, but statistical comparison of data from these sites (by establishing a multi-site trial) is more feasible than for sites from different regions. If the aim is to select clones or rootstocks suitable across a whole region, then all sites within the region should have the same set of clones or rootstocks to enable efficient comparisons of the different genotypes. The sites should have standard vine and row spacings and common trellising and training systems, so that these effects are not confounded with the site effects.

Within vineyards

Even within a vineyard or a varietal block, variation in climate and soil can occur. Vines protected by a windbreak will differ from those that are exposed. Soil characterisation prior to establishment will define soil variations. Trials need to be designed correctly to account for these variations.

3.1.2 Temporal variation

Climatic conditions vary dramatically over years at the same site. The statistical analysis of data over years requires a repeated measures analysis. Climatic data should be recorded and year-to-year variability considered, when interpreting the results of trials. Soil characteristics may also change with time e.g. soil acidification due to inappropriate use of nitrogen fertiliser, and this may be important when evaluating rootstock trials. Changes in management practices such as pruning level or irrigation strategy may be unavoidable, where trials are established in grower vineyards. Any such changes must be well documented.

3.1.3 Source vine variation

Often there is variation in the quality of the vines in a batch of planting material e.g. differences in stem thickness, root number and thickness, and shoot length and bud development. Vines should be sorted and any weak or excessively strong vines rejected, as these will influence the rate of establishment of vines in the trial. The aim should be to reduce the variation within the vines of the same clone or rootstock i.e. to have them as even as possible.

3.2 Trial design

3.2.1 Basic principles

Variability

In any trial, variability between vines e.g. due to site or planting material variation, hinders the detection of differences between genotypes. Generally, the greater the expected variability within the trial, the greater the number of vines required to detect differences. Much of the variation can be accounted for in the trial design, by randomising the planting of genotypes. Genotypes are also commonly grouped into blocks (as randomised complete block trials), where each block (or replicate) in the trial layout is made as uniform as possible to minimise the effect of field trends e.g. due to soil variation.

Repeating the 'blocks' across a trial area is called replication. The appropriate number of replicates can be determined when the trial is designed, by using variability information gained in previous trials, and making decisions on the degree of confidence needed in the result and the level of difference that it is required to detect between treatments.

In most cases the level of confidence can be set at 90%, so that there is one chance in 10 that the answers from the trial work will be wrong. Increasing the level of confidence to say 99% substantially increases the number of replications, and reducing the level of confidence to 80% creates an unacceptable risk (i.e. one in five) that the trial results will produce a 'wrong' answer.

A decision is needed on the detectable difference required between treatments. For yield this may be 10 or 20%, but for sugar concentration (°Brix) a difference of 5 to 10% may be important. Variability information obtained from previous trial work in one region, expressed as percentage coefficient of variation, is given in Table 3-1.

Table 3-1 Percentage coefficient of variation for parameters commonly measured in clonal and rootstock trials

	Clonal	Rootstock
Yield per vine	25-45	25-50
Bunch number per vine	20-35	25-40
Bunch weight	15-25	15-25
Berry number per bunch	15-25	15-30
Berry weight	5-15	8-15
Soluble solids (°Brix)	3-5	4-6
Titratable acid	5-10	7-11
pH	1-3	2-4
Colour	13-18	13-18

Percentage coefficient of variation information in Table 3-1 can be used in Table 3-2 to give the approximate number of replications required for designing experiments to provide the required percentage detectable differences, at a significance level of 5% (Type I error) and a probability of significant difference of 90% (Type II error) (Cochran and Cox 1957). If the percentage coefficient of variation for measured parameters is less at a particular site, then the number of replications required will be less.

Table 3-2 Replications required in designing trials for a required level of precision

Percentage detectable difference	Percentage coefficient of variation				
	5	**10**	**20**	**30**	**50**
5	22	85	337	757	2102
10	6	22	85	190	526
15	3	10	38	85	234
20	3	6	22	48	132
25	3	4	14	31	85
30	3	3	10	22	59

3.2.2 Small plot trials

Layout

Initial genotype assessments are normally conducted in small plot trials. Vine spacing should be chosen to reflect that commonly used in the region. For clonal trials, candidates will usually be of similar vigour, so they can be designed without buffer vines i.e. using single vine plots. However, if the trial is of a variety with clones that have large differences in vine habit e.g. Pinot Noir, the use of buffer vines may be of benefit. Plots of 3 or more vines may also be used for ease of harvest.

For rootstock trials, large vigour differences may be expected, depending on the site characteristics, and test vines should be separated by buffer vines within the row i.e. at least 3 vines per plot should be used with the central vine being measured. It is more efficient to use 4-6 vine plots and measure the central 2-4 vines (e.g. for a 5 vine plot 60% of the vines are then used for measurement as compared to only 33% with a three vine plot). Three vine panels are commonly used and if rootstock plots are to have labels on posts for growers to make their own visual assessments, it is convenient to use 3 or 6 vine plots.

For plots of more than one vine, yield and quality parameters can be separately measured on each vine assessed, or where resources are limited, on a whole plot basis i.e. without keeping individual vine data of measured vines in a plot separate.

Trial design

Randomised complete block designs have been most commonly used in the past for small plot trials. The natural arrangement of vines in trellised rows also lends itself to the use of row-column designs (resolvable or less commonly non-resolvable), where rows are the vine rows and columns are the vine positions within a row (Table 3-3). The latin square is the classic design of this type where a complete set of genotypes appear in every row and every column. However, in practice it is often difficult to have as many rows and columns as there are genotypes. There are many variations on the row-column theme; an incomplete block design is one such example (John and Williams, 1995). These designs are effective when there are field trends along rows or columns.

It is difficult to be totally prescriptive about which trial design to use at each site. For one to several rows, a randomised complete block is likely to be adequate, but for more rows, row-column designs with nearest neighbour balance should be considered. Table 3-3 is an example of a row-column design with nearest neighbour properties. Always generate the design and randomise the genotypes separately for each site. Specialist computer programs are available to assist with the design of trials e.g. Genstat or SpaDes. As field trials are very expensive to set up and to maintain, it is highly recommended that a biometrician be consulted at the design stage.

Table 3-3 Row column design

	Col 1	**Col 2**	**Col 3**	**Col 4**	**Col 5**	**Col 6**	**Col 7**	**Col 8**	**Col 9**	**Col 10**
Row 1	9	8	1	6	5	4	10	2	7	3
Row 2	7	4	5	3	8	1	9	6	2	10
Row 3	5	10	2	4	3	9	8	7	6	1
Row 4	6	3	8	7	2	10	1	5	9	4
Row 5	2	1	10	9	7	6	4	3	5	8

3.2.3 Larger plot trials

Whole row plots

Randomised complete block design trials with whole row plots of even length can be used for larger scale evaluation at the pre-release stage. The use of entire rows enables the assessment of mechanically harvested fruit if a weighbridge is nearby, so the trial reflects commercial reality. The experimental unit is the row, so only the total yield of the row is recorded and a representative sample is taken from grapes harvested from each row for quality measurements. Whole row plots integrate the soil and other trends that occur down the row and will only be effective if all rows in a block have the same variation down each row. For this reason the rows should be grouped into small blocks. However, the number of blocks (replicates) in this type of trial may need to be comparable to that of a small plot trial and because of the large size of the plots, only a small number of genotypes can be tested. Although competition between different rootstocks could occur across the rows, it is unlikely to be a serious problem, because such a trial would normally only contain similar genotypes that have the potential to become recommended for use. As with small plot trials, it is important to collaborate with a biometrician in the design stage of whole row trials.

Commercial size fermentation trials

A trial of this type may require 10-50 tonnes of grapes per fermentation, so each plot would be comprised of 1-2 hectare rectangular plots, each containing a single genotype. The trial size would need to be very large with the potential for large variation among the plots, making it difficult to conduct in the non-uniform soil situations usually found at each site.

3.3 Trial management

3.3.1 Clonal trials

Clonal trials will have greater relevance if rootstock, canopy management and irrigation reflect current or future practice for the particular region (although this may be constrained by grower requirements in the trial vineyard). Where grafted vines are usually used in a region, all clones should be grafted onto a commonly used rootstock. Canopy management is important because a strong interaction may occur between this and the yield of clones – the performance of clones with higher growth and yield potential can be restricted by severe pruning (Clingeleffer, 1988).

Management should also reflect industry expectations with respect to what an improved clone should offer e.g. the need to develop small, loose bunches with small berries to assist botrytis control. Consequently the selection of trellis design and fruiting unit (e.g. spur or cane pruning and length of these) is critical. Uniform hedging of vines will often be appropriate, but if this method is not used, pruning should be as light as possible to allow a greater chance of differentiation of clones. Vertical training may be appropriate in some cooler regions.

3.3.2 Rootstock trials

There will commonly be large differences in vigour between different rootstocks in the early selection phase where selections are tested in small plot trials. Historically, in these trials management has usually been the same for all rootstocks. However, in a normal vineyard situation with larger areas of grafted vines, it is possible to vary management practices, such as irrigation or pruning, to better control high vigour stocks. Consideration could be given in future to superimposing say two irrigation or pruning treatments in the design to more closely investigate management of rootstocks with large differences in vigour.

3.4 Statistical analysis

The statistical package GENSTAT is ideal for the analysis of both small and larger trials.

3.4.1 Small plot trials

Small plot trials should initially be analysed on a site-by-site basis. Analysis of variance or an equivalent form of testing can be used to assess the differences between genotypes. In trials with a row-column design, a randomised block analysis could be performed initially. However, an analysis that includes effects to allow for both the variation between rows and the variation between columns before estimating the genotype effects is preferred. If the design is not completely balanced, some non-standard analysis will be required. The Residual Maximum Likelihood (REML) approach can be used (Patterson and Thompson, 1971). This method enables the information about genotypes that resides in the 'between rows' and 'between columns' to be incorporated into the estimate of the genotype effects. Significant gains in efficiency can sometimes be made using this technique. The REML analysis can be extended to incorporate the correlation in errors that occurs between adjacent plots.

Data should be analysed within each year. Pooling data over a period of years may be relevant if there are no year x treatment interactions.

Competition effects in rootstock trials will normally be overcome by including buffer vines in the layout. If there is still a need to remove these effects, this can be achieved by following the technique of Correll and Anderson (1983). Multi-site trials can be examined in a single analysis provided there is sufficient overlap of genotypes, but it is recommended that a biometrician be consulted to deal with the statistical issues involved.

3.4.2 Larger plot trials

A randomised block analysis can be used on the yield or quality measurements recorded on whole rows. Other techniques such as REML could also be used.

3.4.3 Fermentation trials

Fermentation trials may be conducted on small or larger plot trials. The variable of interest in the trial may be a measurement (e.g. pH of the wine) or a taste test. In each case, the effects of the genotype must be related back to between fermentation variance, which will include a variance component from among the field plots, plus a component from the fermentation process. Pooling fruit from field blocks and then splitting it for fermentation replicates masks the field variability. Taste testing is performed by a tasting panel over several sessions and requires careful experimental design (Brien and Payne, 1999).

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4. Climatic definition

4.1 Sources of climatic data

4.1.1 Bureau of Meteorology

To define the climate at the site, Bureau of Meteorology (BM) data may be used. Data are available in a number of forms:

- Climatic averages and daily datasets (including satellite derived radiation data) can be obtained on the BM web site **http://www.bom.gov.au/.**
- Continuous daily meteorological datasets for modellers and researchers are available through SILO .(**http://www.bom.gov.au/silo/** or **http://www.dnr.qld.gov.au/silo/**). The Patched Point Dataset, which combines original BM measurements for a particular station with interpolated data, provides a dataset with no gaps. The Data Drill provides interpolated data for any location in Australia.
- BM data are available in computer packages e.g. MetAccess from Horizon Technology.
- Data summaries are available in monographs e.g. Dry and Smart (1988) and Gladstones (1992).
- Providers of Geographic Information Systems (GIS) may also have climatic data available.

4.1.2 Unpublished sources

Data may be available from weather stations located on vineyards and farms. There is increasing use of automatic weather stations in vineyards.

4.1.3 Data reliability

Reliability of data from any particular meteorological station should be evaluated. Site problems which can occur include presence of trees, lack of maintenance, the possibility that the site has been moved or changed and cold air drainage effects. Problems can be uncovered by contacting the person responsible for collecting or maintaining the data. Note also that long-term average data does not reflect variability between years, and it must be recognised that in any year this variation can be quite significant.

4.2 Climatic indices

Data for Adelaide (Waite) used in the following examples can be obtained from the BM web site.

4.2.1 Temperature

Mean daily temperature

Mean daily temperature for each month = (mean daily maximum + mean daily minimum)/2
e.g. for Adelaide (Waite) mean daily temperature for August = (15.2 + 8.1)/2 = 11.7 °C

Mean January temperature

Mean January temperature (MJT) is used for the southern hemisphere and mean July temperature for the northern hemisphere (Dry and Smart 1988).
e.g. for Adelaide (Waite) MJT = (27.7 + 16.2)/2 = 22.0 °C

Mean annual range (continentality)

Mean annual range = mean January – mean July temperature (for southern hemisphere).
e.g. for Adelaide (Waite) mean annual range = 22.0 – 10.9 = 11.1
The Gladstone (1992) method for mean annual range = mean of hottest month – mean of coldest month
e.g. for Adelaide (Waite) the Gladstone mean annual range = 22.1 – 10.9 = 11.2

Day degree summation:

With the standard day degree method, for each month the mean daily temp (°C) less 10, is multiplied by the number of days in the month and the total obtained for October to April inclusively.

e.g. day degrees for October at Adelaide (Waite) = (15.6 – 10) x 31 = 174°.

Day degree summation for October to April inclusively = 174 + 240 +318 + 372 + 339 + 326 + 216 = 1985

The Gladstone (1992) method is as above, but truncated at 19°C i.e. any month with mean 19°C or higher is calculated as 19 (279 maximum for month) and the total obtained for October to April inclusively.

The Gladstone day degree summation for October to April inclusively = 174 + 240 + 279 + 279 + 252 + 279 + 216 = 1719.

4.2.2 Relative humidity

Relative humidity is recorded daily at 9 am and 3 pm at most BM stations. More frequent records are available where automatic weather stations are used. Climatic indices for relative humidity % generally fall into two categories:

- Average 3 pm relative humidity % October to April (Dry and Smart 1988)
- Mean 3 pm relative humidity % for each month

(3 pm relative humidity % data are not available for Adelaide (Waite).

Relative humidity data have implications for disease and pest control.

4.2.3 Rainfall

Rainfall (mm) is generally recorded each day at most BM stations. Climatic indices used are:

- Mean rainfall for each month (mm)
- Mean rainfall (mm) total October to March (Dry and Smart, 1988)
- Mean rainfall (mm) annual (Dry and Smart, 1988)

e.g. for Adelaide (Waite)

Mean rainfall (mm) total for October to March = 189.7

Mean rainfall (mm) annual = 621.2

Rainfall data have implications for irrigation requirements and disease and pest control.

4.2.4 Sunshine hours

Sunshine hours (SSH) are measured as hours of bright sunshine per day. Data are only available from some BM weather stations. Data can be used from a nearby station or interpolated from a climatic atlas. Climatic indices used are:

- Mean daily SSH for each month
- Total SSH October to April (Gladstones, 1992)
- Mean SSH October to March (Dry and Smart, 1988)

e.g. for Adelaide (Waite)

Mean SSH October to March = 7.0 + 7.9 + 8.5 + 9.5 + 9.1 + 7.5 = 49.5/6 = 8.25.

4.2.5 Solar radiation

Solar radiation is recorded in units of Megajoules (MJ) per unit time. This information is only available from some BM weather stations, but synthetic data on any geo-referenced point within Australia can be obtained from SILO's data drill (**http://www.dnr.qld.gov.au/silo/**).

4.2.6 Evaporation

Evaporation is measured in Australia using a Class A pan. Climatic indices are:

- Annual Class A pan evaporation (mm)
- Mean daily Class A pan evaporation for each month (mm)
- Total October to March Class A pan evaporation (mm) (Dry and Smart, 1988)

e.g. for Adelaide (Waite)

Annual Class A pan evaporation (mm) = 1524.4

Total October to March Class A pan evaporation (mm) = 133.3 + 168 + 207.7 + 229.4 + 198.8 + 164.3 = 1101.5

4.2.7 Spring Frost Index

Spring frost index (SFI) in the Southern Hemisphere is the average mean temperature minus the average lowest minimum temperatures °C for October-November (Gladstones, 2000).

4.3 Methods to use when measured data are not available

4.3.1 Use the SILO Data Drill.

The SILO Data Drill (http://www.dnr.qld.gov.au/silo/) will give a daily climate dataset that starts on the 1st January, 1889 to present. This dataset is extracted from interpolations of all available BM measurements of rainfall, minimum and maximum temperatures, radiation, evaporation and vapour pressure. Note that the rainfall measurements, and hence the daily interpolations, are available from 1/1/1889, but the other measurements, temperatures etc., are available from 1957 to present (1970 to present for evaporation). Therefore, prior to 1957 (or 1970), long-term daily average datasets are supplied.

4.3.2 Interpolation from climatic atlases e.g. sunshine hours, evaporation

If data are available for October, January, April, July, estimate values for November, December, February, March and calculate total (SSH or evaporation) for October to April.

4.3.3 Regression and interpolation using data from nearby stations

This assumes that there is a close relationship between elevation, for example, and the climatic parameter e.g. assume vineyard site S is at 200 m elevation. Meterological station A is at 100 m, B at 300 m and C at 400 m and all are within a 50 km radius of S. First plot maximum (or minimum) daily temperature for desired month (y axis) against elevation (x axis) and fit a line. Then calculate equations of the line and estimate value for 200 m. This works best for temperature, evaporation and rainfall. Extrapolation is possible, but may be risky.

4.3.4 Evaporation data

Evaporation data are only available from some of BM stations. Data are also collected in some vineyards. Use interpolation from a climatic atlas (for non coastal locations), interpolate from nearby stations or calculate from climatic averages using the following:

$$Eo = \frac{[700Tm/(100 - A)] + 15(T - Td)}{80 - T}$$

Where

Tm	=	T + 0.006h
h	=	elevation (m)
T	=	mean daily temperature for month (°C)
A	=	latitude
Td	=	mean dew point (°C)
Epan	=	Eo x 1.15 x number of days in month

4.3.5 Correction for difference in elevation (altitude) without calculating regression

Add 0.6 °C for every 100 m the site is lower than the recording station or subtract 0.6 °C for every 100 m the site is higher than the recording station – adjust both maximum and minimum temperatures.

4.3.6 Correction factors for topography and soil type

Correction factors which can be used are given in Table 4-1.

Table 4-1 Correction factors for topography and soil type

Factor	Min temp	Max temp
Moderate slope, undulating terrain	+1.0	– 0.5
Steep slope, free-standing hills	+ 1.5	– 0.5
Slopes facing sun	+ 0.75	+ 0.25
Stony, rocky or calcareous soil	+ 1.0	– 0.5

From Gladstones (1992) adjusted relative to loamy soil and flat terrain.

All adjustments are additive and are assumed to apply uniformly over the whole season.

4.4 Suggested datasets

Long term data available can be tabulated as shown in Table 4-2. Annual data should also be presented of daily minimum and maximum temperatures and rainfall for each year the trial is assessed, preferably as graphs which also include long term data. Location and climatic indices can be presented as shown in Table 4-3.

Table 4-2 Long term climatic averages for Adelaide (Waite)

Month	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Annual
Mean daily minimum temp (°C)	7.7	8.1	9.2	10.9	12.8	14.7	16.2	16.5	15.4	12.9	10.7	8.5	11.9
Mean daily maximum temp (°C)	14.1	15.2	17.5	20.2	23.2	25.8	27.7	27.6	25.6	21.4	17.8	15.0	20.9
Mean daily temp (°C)	10.9	11.7	13.4	15.6	18.0	20.3	22.0	22.1	20.5	17.2	14.3	11.8	16.5
Mean 9 am relative humidity (%)	76	71	64	59	54	50	49	52	53	61	68	75	61
Mean 3 pm relative humidity (%)[1]													
Mean rainfall (mm)	87.6	75.4	63.5	52.2	36.7	29.5	23.8	23.5	24.0	52.0	76.4	76.6	51.8
Mean daily sunshine (hrs)	3.4	4.4	5.4	7.0	7.9	8.5	9.5	9.1	7.5	5.5	4.0	3.3	6.3
Solar radiation													
Mean daily Class A pan evaporation (mm)	1.6	2.2	3.1	4.3	5.6	6.7	7.4	7.1	5.3	3.4	2.1	1.5	4.2

[1] Not available for Adelaide (Waite)

Table 4-3 Location and climatic indices for Adelaide (Waite)

	Climatic station	Vineyard site
Latitude	34.9697 S	
Longitude	138.6331 E	
Elevation (m)	115.0	
Mean January temp MJT (°C)	22.0	
Mean annual range MAR	11.1	
Frost index		
Day degrees (base 10)	1985	
Sunshine hrs October – April total	1664	
Average 3 pm RH % October–April [1]		
Mean rainfall total October – March (mm)	189.7	
Mean rainfall total annual (mm)	621.2	
Class A pan evaporation total October–March (mm)	1101.5	

[1] Not available for Adelaide (Waite)

4.5 Further reading

Dry, P.R. and Smart, R.E. (1988). The grapegrowing regions of Australia. In B.G. Coombe and P.R. Dry *Viticulture Volume 1 Resources in Australia,* Winetitles: Adelaide

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Gladstones, J. (1992). *Viticulture and environment.* Winetitles: Adelaide

Gladstones, J. (2000). Past and future climatic indices for viticulture. *Australian and New Zealand Wine Industry Journal,* **15:2**, 67, 69-71, 73.

5. Soil and water definition

5.1 Site selection

5.1.1 General location

Trial sites should be selected so that they are representative of existing or potential viticultural soils of the region. Possible sources of information on soils include:

- District or regional soil maps, soil landscape maps and land system maps (but continental scale maps e.g. Atlas of Australian Soils are too coarse)
- Unpublished material from the state agency responsible for land resource assessment
- Local knowledge – this may be the only fall back in some situations
- Providers of GIS services.

5.1.2 Actual site

A site should be selected with uniform topography and soil features. When a potentially uniform site is located, a detailed survey can be conducted to define the site and finally locate the trial. A survey grid as close as 10 m x 10 m may be needed to identify soil variations. Holes should be dug with an auger or press tube to minimise disturbance.

5.2 Soil characterisation

Soil characterisation at the trial site is particularly relevant for rootstock trials. Examination of a soil sampling pit (Maschmedt and Nicholas, 2003) is the best way to do this, as most published soil or land resource maps are lacking in sufficient detail. Soil profile characteristics which should be recorded are given in Table 5-1 and chemical analyses in Table 5-2 and a datasheet is provided as Table 5-5. A photo should be taken of the pit. If there is an unavoidable variation in soil type across the site, more than one pit will be required. Note that variations in thicknesses of different layers, although possibly significant from an irrigation management point of view, do not constitute differences in soil type unless extreme. The geological setting of the site should also be understood, particularly as it affects deep drainage. The soil should be classified according to 'A key for classifying viticultural soils' given in Maschmedt et al (2002). Soil classification is further discussed by Maschmedt (2003).

Preplant soil amelioration e.g. uniform application of lime or gypsum may be required as part of standard establishment practice. Relevant pre-amelioration data should be collected, but the main emphasis for data collection should be on the ameliorated soil (i.e. what the vine will actually be growing in).

The effective rootzone depth can be estimated from the soil profile description, chemical analyses and from Table 5-3. Note, however, that some rootstocks may grow through some barriers e.g. carbonate layers and others may not. The volume of soil water stored between field capacity and a range of soil moisture tensions is given in Table 5-4. Of most interest is the -8 to -60 kPa range, which is the readily available water (RAW). To calculate the total rootzone RAW multiply the thickness of each layer in cm by the RAW (mm/cm) of the field texture in Table 5-4 and add these for the layers in the effective rootzone.

Table 5-1 Soil profile description

Whole profile
Depth to hard rock or hardpan
Depth to water table
Depth to impermeable substrate material
Drainage (susceptibility to waterlogging) [1]
Each layer
Boundary distinctness[1]
Texture[1]
Gravel/stone content[1]
Colour[1]
Structure/consistence[1]
Dispersion[2]
Carbonate (effervescence, class, %)[1, 3]
Other segregations (e.g. ironstone) [1]

[1]See McDonald et al (1990)

[2]See Emerson (1991)

[3]Only needed in regions where soils are known to be calcareous and/or contain salts

Table 5-2 Chemical analyses of soil samples

Analysis	**Units**	**Code**[1]
pH_w and pH_{Ca}		4A1, 4B2
$EC_{1:5}$	dS/m	3A1
EC_e on saturation paste (determine if $EC_{1:5}$ values exceed 0.15 dS/m (sands), 0.2 dS/m (loams) or 0.3 dS/m (clays)	dS/m	14B1
CEC and exchangeable cations (neutral to acidic soil)	cmol(+)/kg (or meq/100g)	15B2
CEC and exchangeable cations (alkaline soil)	cmol(+)/kg (or meq/100g)	15C1
CO_3[2]	%	19B1
Sulphate (KCl_{40} method)[2]	mg/kg	
Chloride[2]	mg/kg (or %)	5A1
Boron[2]	mg/kg (µg/g or ppm)	12C2
Organic carbon (acid to neutral soils) [3]	%C	6B2
Organic carbon (calcareous soils) [3] - total C and CO_3-C	%C	6B2, 19B1
Organic carbon (highly calcareous soil with low organic matter)[3]	%C	6B1
Available (extractable) phosphorus[3]	mg/kg (µg/g or ppm)	9B2
Available (extractable) potassium[3]	mg/kg (µg/g or ppm)	18A1
Trace elements (EDTA) [3]	mg/kg (µg/g or ppm)	12B1

[1] Analysis method code given in Rayment and Higginson (1992)

[2]Only needed in regions where soils are known to be calcareous and/or contain salts

[3]Optional nutrient analysis

Table 5-3 Depth that grapevine roots penetrate in a range of soil materials

Soil material	Depth of vine root penetration
Top soil	All of layer
Ironstone gravel lens	All of layer
Weathered rock	70cm of layer
Sandy loam to clay loam subsoil with friable structure (sub-angular blocky pedality)	All of layer
Sandy loam to clay loam subsoil with dense structure (medium to strong columnar, prismatic or lenticular pedality)	70cm of layer
Clay B horizon with friable structure (medium to strong angular blocky or sub-angular blocky pedality)	50cm of layer
Clay B horizon with dense structure (medium to strong columnar, prismatic or lenticular pedality)	20cm of layer
Class l carbonate layer – fine soil carbonate in clay.	20cm of layer
Class IIIAL carbonate layer – compact mixture of sandy clay loam to light clay and fine soil carbonate.	30cm of layer
Class IIIAS carbonate layer – compact mixture of loamy sand to light sandy clay loam and fine soil carbonate.	50cm of layer
Class IIIB carbonate layer – as for III and IIIAL except that calcrete fragments account for 30-60% of layer	50cm of layer
Class IIIC carbonate layer – as for IIIAS and IIIAL except that fragments account for >60% of the layer.	50cm of layer
Class IIB and IIR carbonate layer – sheet or boulder calcrete, hard with whitish or pinkish colour.	50cm of layer if ripped
Note: Maximum rootzone is limited to a depth of 150cm for irrigation design purpose pre-development. However in existing vineyards if the observed rootzone exceeds 150 cm that is the figure used.	

Source Wetherby (2003)

Table 5-4 Volume of soil water (mm/cm depth of soil) stored between field capacity (-8kPa) and a range of soil moisture tensions for different soil textures

Texture	Soil moisture tension (kPa)				
	-8 to -40	-8 to –60	-8 to -200	-8 to -400	-8 to -1500[1]
S	0.36	0.37	0.46	0.49	0.62
LS	0.52	0.55	0.65	0.70	0.86
CS[2]	0.55	0.60	0.74	0.80	1.01
SL	0.59	0.64	0.84	0.92	1.15
LSCL	0.65	0.74	1.03	1.11	1.37
L	0.69	0.84	1.00	1.11	2.34
SCL	0.61	0.71	1.01	1.13	1.43
CL	0.53	0.65	1.03	1.16	1.48
C	0.46	0.57	0.90	1.09	1.49
HC	0.25	0.41	0.49	0.59	1.20

[1]Wilting point is at –1500 kPa

[2]Interpolated value

Source: Primary Industries and Resources South Australia and Wetherby (2003)

5.3 Soil water status

Climate based calculations of soil water status using an evaporation pan or data from a weather station provide estimates of evapotranspiration, but have some limitations e.g. they do not give reliable estimates of the water held in the rootzone at the beginning of the season, or the effectiveness of rainfall. The use of soil sensors e.g. tensiometers, electrical resistance blocks or capacitance probes can overcome some of these limitations, particularly if continuous monitoring is conducted. Another alternative is the gravimetric determination of soil water status by soil sampling and determination of soil water content in the laboratory.

In small plot trials, two different water application treatments might be superimposed on the trial using drip irrigation (e.g. full seasonal requirements of the vine and regulated deficit irrigation) and soil water monitored for several rootstocks for each water application treatment. Data obtained will be useful in the assessment of rootstock characteristics e.g. drought tolerance or susceptibility to waterlogging.

5.4 Suggested datasets

The following soil data and information should be collected for rootstock trials if funds are available.

- Soil characteristics as in Table 5-5.
- Soil classification by the 'Key for identifying categories of vineyard soils in Australia' as described in Maschmedt et al (2002) and Maschmedt (2003).
- Nematode counts and presence or absence of phylloxera.
- Soil water content at budburst, flowering, veraison and harvest determined gravimetrically on at least 3 replicate samples.

5.5 Further reading

Emerson, W.W. (1991). Structural decline of soils, assessment and prevention. *Australian Journal of Soil Research* **29**, 905-921.

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Wetherby, K. (2000). Calcareous soils at McLaren Vale. *Australian Viticulture* **4:6**, 16-17.

Wetherby, K. (2003). *Soil description book*. Ken Wetherby, Cleve SA 5640

Table 5-5 Soil characteristics

Site: **Hundred/Parish:** **Easting:**

Owner: **Section:** **Northing:**

Physical characteristics

Layer #	Depth	Boundary Distinctness	Texture	Gravel %	Colour	Structure	Consistence	Dispersion	Profile data	
									Depth to hard rock	
									Depth to hard pan	
									Depth to water table	
									EC of water table	
									Depth to impermeable layer	
									Drainage (susceptibility to waterlogging)	
									Effective root zone depth	
									Estimated RAW	

Chemical characteristics

Layer #	Depth	pH		EC dS/m		Carbonate			Cl mg/kg	SO_4 mg/kg	Org C %	Avail. P mg/kg	Avail. K mg/kg	Boron mg/kg	Trace elements mg/kg				CEC cmol (+)/kg	Exch. cations cmol(+)/kg			
		PH_w	pH_{Ca}	$EC_{1:5}$	EC_e	Eff	Class	%							Cu	Zn	Mn	Fe		Ca	Mg	K	Na

6. Trial measurement

6.1 Phenology

Grapevine growth stages can be recorded for comparisons at different sites, or for vines on different rootstocks at a particular site, by referring to Figure 6-1 (Coombe 1995). Important stages are budburst (Coombe 4), full bloom (Coombe 23), veraison (Coombe 35) and harvest (Coombe 38). To determine when a growth stage is reached, observe shoots at 'count node two' on spurs and the most distal node on canes and record the dates when 50% of the nodes reach each of the growth stages.

6.2 Canopy measurements

6.2.1 Canopy surface area

The canopy surface area per metre of row or vine influences potential yield and rate of ripening. It can be determined by height x width measurements (Smart and Robinson 1991), when vines are fully grown (between veraison and harvest).

6.2.2 Leaf layer number and fruit exposure

The point quadrat method of Smart and Robinson (1991) gives a useful measure of fruit exposure in canopy systems where the bunch zone lies in a discrete area. It is assessed by passing a fine rod through the canopy (representing a ray of light) noting when the rod ‘hits’ leaves or bunches. It gives an indication of the proportion of leaves and fruit which are exterior or interior in the canopy. Alternatively, ceptometer or Li Cor canopy analyser LA1-2000 meter measurements can be made if these instruments are available. A ceptometer can give a quantitative value for % bunch exposure. The LA1-2000 gives apparent leaf area which can be converted to actual leaf area using a regression equation (Sommer pers. com.).

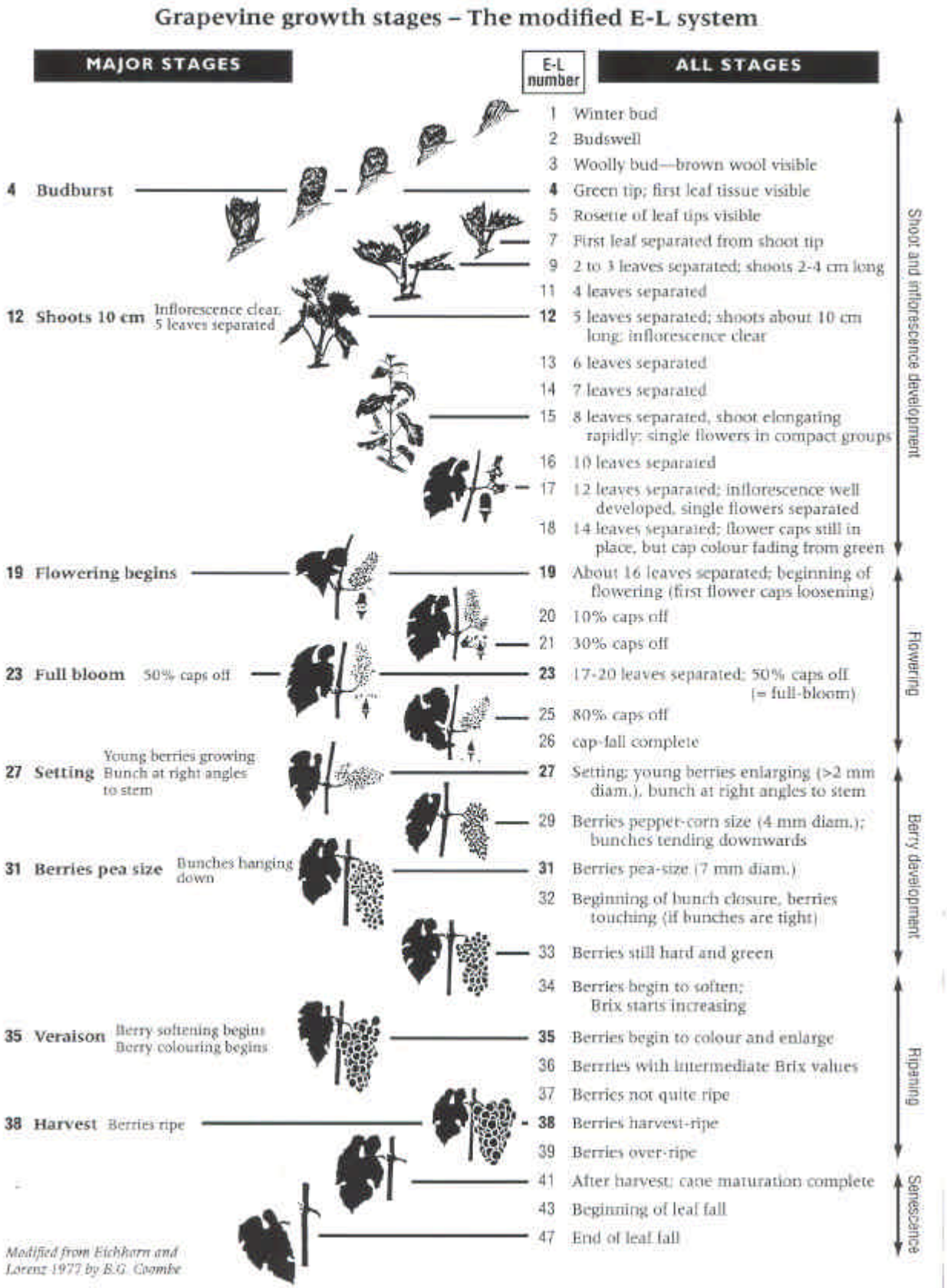
6.2.3 Fruitfulness

Assessment of fruitfulness before flowering using the Merbein bunch count technique (Antcliff et al 1972) gives % fruitful burst nodes. Basically the number of nodes, shoots and bunches are counted over a section of the vine and estimates of fruitfulness and other characteristics calculated. This is a time consuming method, but provides information on appropriate fruiting units to leave at pruning. A change in fruiting unit (e.g. more canes or longer spurs) may allow better control of vigour induced by vigorous rootstocks leading to their future use, rather than being discarded. For lighter pruning systems, a 20 cm transect over each vine using a rope ladder, can be used to reduce the work load (Krstic pers. com.).

6.2.4 Pruning weight

Pruning weight is recorded for each vine during dormancy to provide an indication of vine capacity. In the case of cane pruning, the weight of one year growth removed from the vine is recorded, excluding that retained to lay down new canes. Prunings are bundled and measured with scales. Pruning weight is usually too difficult to record for minimally pruned vines.

Figure 6-1 Grapevine growth stages



6.3 Other vine observations

Graft unions can be observed for anomalies to identify potential incompatibility problems caused by virus infection (Krake et al 1999). The chances of incompatibility are likely to be greatly reduced if clones used in future trials have tested free of viruses that are known to be implicated in graft incompatibilities. Other factors which should be recorded if symptoms are present are bunch stem necrosis, nutrient deficiencies, lime induced chlorosis and water stress – particularly in rootstock trials.

6.4 Grape yield and quality

6.4.1 Disease incidence and severity

If disease (e.g. bunch rot) is a problem, incidence and severity should be recorded just before harvest. Assess 20 typical bunches (i.e. 5 from the bunch zone on each quarter of the vine or plot). When assessing each bunch, rotate the bunch and look for diseased (e.g. rotted) berries. For a specified disease, include only berries with characteristic symptoms (e.g. for Botrytis rot, only berries with sporulating growth of *Botrytis cinerea*). If there are different amounts of disease on each side of the bunch, rotate the bunch until an average amount of diseased berries is visible. Estimate the severity of disease on the bunch (i.e. the percent area of the bunch with disease) by comparing your image of the bunch with the diagrammatic key (Figure 6-2). Assign the bunch to one of the categories shown in the figure on the basis of the proportion of berries diseased. Categories of disease and their mean scores (percent bunch area diseased) are given in Table 6-1. The upper range of each category (denoted * in the table) is depicted diagrammatically in Figure 6-2 with the shaded area on each bunch representing the area diseased.

Table 6-1 Categories of disease severity and their mean scores

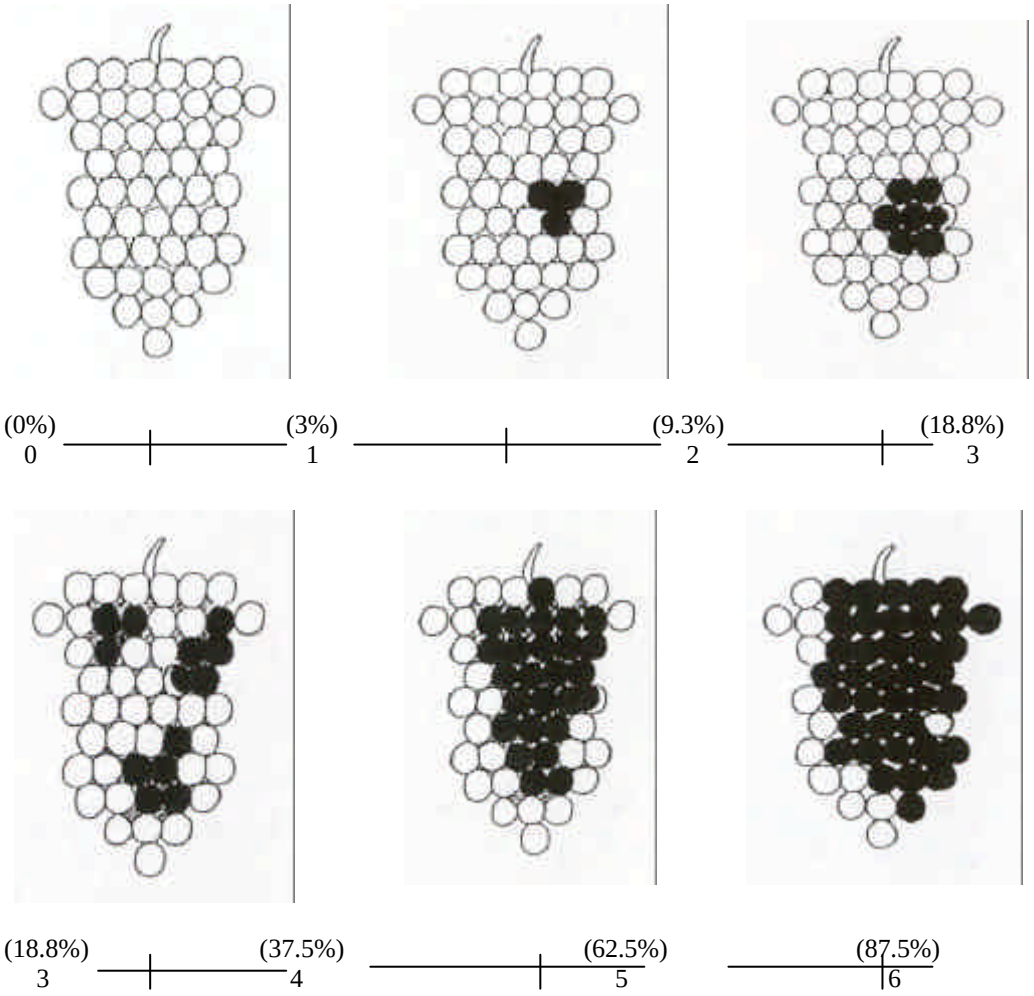
Category number	Range (% area diseased)	Mean score (% area diseased)
0	**0 ***	**0**
1	**> 0 – 6 ***	**3**
2	**> 6 – 12.5 ***	**9.3**
3	**> 12.5 – 25 ***	**18.8**
4	**> 25 – 50 ***	**37.5**
5	**> 50 – 75 ***	**62.5**
6	**> 75 – 100**	**87.5**

Determine the incidence and severity of disease for each vine or plot as follows:

- Disease incidence (i.e. mean percent of bunches diseased) = number of bunches with % area diseased > 0 divided by the number of bunches assessed (20) multiplied by 100.
- Disease severity (i.e. mean percent of bunch area diseased) = sum of mean scores (% area diseased) divided by the number of bunches assessed (20).

Compile the incidence and severity scores in a spread-sheet and calculate means for each vine or plot and standard deviations. During analysis of the data (percentages), use appropriate transformations.

Figure 6-2 Diagramatic key for the assessment of disease severity on grape bunches



6.4.2 Grape sampling

Grape samples should be collected on a weekly basis for maturity testing and compositional analysis. Ideally sampling should commence at veraison, or at least 3-4 weeks prior to actual harvest. A maturity curve can be plotted for each genotype to predict when it should be harvested at a particular ripeness i.e. ^{o}Brix (or Baume).

Ideally the smallest sampling unit should be a bunch (where a bunch is defined as having more than 5 berries), and samples should be collected from vines which have not been designated for yield assessment. Five bunches per vine should be sampled to account for the within-vine variability which exists in ^{o}Brix, pH, titratable acid and colour. If there are several rows in a plot, bunches should be selected on a 'diagonal transect' in a way which will account for the varying influences of each side of the vine, and exposed versus shaded bunches, on fruit composition.

If the amount of fruit per experimental plot is limited, berry samples should be taken (100 berries per sample, comprised of 5 berries from each of 20 bunches evenly distributed over the vine). An exact count of 100 berries makes weighing to determine berry weight a quick process. For low yielding vines, especially in cooler regions, it is preferable to take 50 berries (5 berries from each of 10 bunches). Note that berry samples may satisfactorily represent maturity in loose bunch varieties, but in compact bunch varieties, the berries sampled are mainly collected from outer layers of the bunch and being riper, can over estimate maturity by 1-2 °Brix.

Sampling time should be kept consistent from one week to the next, preferably in the morning. When samples have been collected, they should be transported to the laboratory in a way which avoids extremes in temperature. In the laboratory, samples should ideally be processed immediately. However, if time is limited some other interim method of storage may be necessary. If samples are stored in a cool room, there will be little effect on °Brix, but a slight increase in the pH and a decrease titratable acid may occur. Freezing samples is generally not recommended, due to the solubility problems associated with potassium bitartrate. Treating samples consistently is the key to minimising error associated with sampling, handling and processing.

6.4.3 Sample preparation and analysis

Weekly berry samples should be soft pressed in a fruit presser, which mimics treatment at the winery. The juice may be allowed to settle or preferably centrifuged and the clear fresh juice used to determine °Brix, pH and titratable acid (Iland et al, 2000). For red varieties an additional set of berry samples is taken for colour determination and frozen. Although colour measurement varies on frozen and unfrozen samples, there is often little time to determine colour during vintage. If all samples are frozen, colour comparisons can be made on samples treated in a consistent manner. Instruments should be calibrated and checked for consistency and accuracy on a regular basis (Iland et al. 2000).

Determine total or potential colour (mg anthocyanins per g berry weight) for red varieties by the method of Iland et al (2000). Some wine companies use Near Infra-red Spectoscopy methodology for colour determination (Dambergs pers. com.), but this method is calibrated with the Iland method. Comparison of colour measurements is only relevant where grapes are at a common °Brix and this may occur at different times for each genotype. Maturity curves will give an indication of when genotypes are at the same °Brix.

For rootstock trials, samples should be analysed for the elements potassium, sodium and chloride. Samples prepared from macerated frozen berries can be analysed or diluted samples of fresh juice may be frozen and later analysed if the method used is stated. Other elements magnesium, calcium, phosphorus, sulphur, boron and nitrogen may be determined where justified in specific investigations.

6.4.4 Yield

To determine yield and its components, harvest each vine separately, at the same time counting bunches. Record the yield weight per vine and calculate the bunch weight i.e. yield divided by the number of bunches. The 100 berry sample taken during maturity sampling is weighed and used to calculate average berry weight and hence berries per bunch can be derived. With lighter pruning systems in warmer regions, a 20 cm transect harvest using a rope ladder can be used, where resources are not available for a full harvest. In cooler climates a 60 cm transect is the optimum sample size (Dunn and Martin unpub.) in terms of precision and time spent sampling. Fruit weight to pruning weight ratio can also be calculated to gauge whether vine growth is in balance – Smart and Robinson (1991).

6.4.5 Wine quality

Small scale winemaking techniques (e.g. 20 L lots) and sensory evaluation of wines have traditionally be used to assess trials (Antcliff and Kerridge 1975). Normally due to the cost, it is not possible to make small lots of wine for each vine in the trial. However, if fruit from vines of the same treatment are bulked, this must be done in such a way that there is not a complete loss of field replication. Two or three fermentation replicates are commonly used and may comprise several adjacent field replications bulked together. If possible, treatments should be harvested for winemaking when they reach a common °Brix, which may involve picking on several dates. More recently small (1000 berry) fermentations have been made from fruit from each vine for colour studies (Iland pers. com.). For trials using whole row plots, one tonne or larger fermentations may be required.

6.5 Leaf analysis

6.5.1 Assessing vine nutrient status

Nutrient status of grapevines can be assessed by sampling and analysing the petioles (leaf stalks) of the leaves from opposite basal clusters. Interpretative standards have only been developed for petioles collected at flowering (50 % cap fall), but for experimental and comparative purposes, petioles can be collected at other identifiable growth stages e.g. veraison. However, the sampling regime must be consistent from year to year, and from site to site.

Because of the cost involved, the need for describing vine nutrient status must be justified in terms of producing new knowledge or explaining variations in performance or suitability to particular soils. Descriptions of rootstock effects on scion nutrient status will normally only be relevant to industry when used to determine specific nutrient management strategies for particular rootstock/scion combinations.

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Comparison of the data with general petiole nutrient standard ranges for petioles sampled at flowering (Robinson et al. 1997) can help explain variability in genotype yields. Different standards may be needed for different districts or for particular stock/scion combinations. Most standards have been developed with reference to grape yields, to which petioles sampled at flowering relate reasonably well. However, petioles sampled at this time are a poor predictor of final grape composition – a more suitable time to sample petioles for this purpose is veraison.

6.5.2 Collection, preparation and analysis of petioles

Although samples of 100 petioles are normal for a commercial vineyard, in trials, 20 petioles taken from small plots can provide sufficient material for a complete analysis. Samples should be cleaned by rinsing in slightly acidified distilled water with several drops of detergent added to remove dust, insects etc., followed by a final rinse in distilled water. Remove surface water by gently rolling the petioles as a group between paper towelling. Record the number of petioles prior to drying them in paper bags at 60°C for at least 24 hours. Determine the dry weight and grind the sample to pass through a 500 µm sieve. Generally, total nutrient analyses are sufficient e.g. total N rather than NO_3-N.

6.5.3 Interpretation of data

Contamination will affect results e.g. copper concentration above 20 ppm is generally due to residual copper spray material. Apparently high manganese and zinc concentrations may also result from foliar spray residues despite washing. High concentrations of aluminium may indicate soil contamination. Petiole dry weights can be recorded to calculate nutrient contents on a whole petiole basis to remove the confounding effect of relative petiole vigour on nutrient concentrations.

6.6 Suggested datasets

The following data should be collected:

- Grape samples – °Brix, acid and pH and for red varieties berry colour – particularly on a weekly basis for rootstock trials. Also potassium, sodium and chloride for rootstock trials.
- Yield and its components.

Collection of other data will depend on the specific aims of the trial and resources available.

6.7 Further reading

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