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VITICARE ON FARM TRIALS

Manual 1

Establishing an On Farm Trial

Traditional On Farm Trial Design

Cooperative
Research Centre
for
Viticulture

Core Participants

About the CRCV

The Cooperative Research Centre for Viticulture is a joint venture between Australia's viticulture industry and leading research and education organisations. It promotes cooperative scientific research to accelerate quality viticultural management from vine to palate. Australian grapegrowers and winemakers are key stakeholders in the CRCV, contributing levies matched by the Commonwealth Government and invested by the Grape and Wine Research and Development Corporation in the Centre.

For more information about the CRCV, please visit www.crcv.com.au.

Disclaimer

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Introduction

Introduction

The Cooperative Research Centre for Viticulture has conducted On Farm Trials since 1999. The initial trials were conducted in eight regions (Port Phillip, North East Victoria, Central Victoria, Adelaide Hills, Riverland, South West Slopes, Riverina and Hunter Valley) and provided Australian growers with the ability to formally assess and validate new science and technology. The trials were conducted over four growing seasons and helped growers to solve problems in their vineyards and improve their management practices.

In 2004 the On Farm Trials project expanded to cover more than 20 viticultural trials primarily in the Riverina, Riverland and Sunraysia regions. Rather than focusing on individual grower issues, the CRCV team has worked with regional grower groups to determine regional issues. The trials are still conducted on a participant growers' property, but a team of people are involved to learn from the trial and to share the workload.

This booklet is part of a series that draws on knowledge gained from this experience in developing and delivering On Farm Trials.

Conducting a trial in your vineyard is not easy and is not a decision that should be made lightly. Although trials can be an excellent method for refining management practices, improving quality or looking for solutions to problems, there are many practical considerations involved in conducting a trial.

At the end of the day, it is your decision about whether a trial is the best option for your business, but this information will give you a starting point for making that decision.

If you choose to undertake a trial, one of the major considerations to be made is trial design. The information included here will guide you through setting up a trial, show you how variation can be taken into account and provide you with some examples of traditional types of trial design.

Why run a trial?

There are many reasons for running a trial. Some of these include:

o IMPROVING MANAGEMENT PRACTICES
Is there a specific management practice that could be improved? For example, it might be that vigour needs to be managed and canopy management is an option for achieving this. When you trial new management practices in local conditions, this allows you to fine-tune the practice to meet your environment.

o TESTING VITICULTURAL PRACTICES
Various viticultural practices can form the basis of a trial. An example is testing irrigation practices such as Regulated Deficit Irrigation (RDI) and Partial Rootzone Drying (PRD).

o MEASURING THE IMPACT OF CHANGES
Understanding the impact of different management practices or changes to the vineyard are often a basis for trials. For example, cover crops might be used to retain soil moisture, but information might be required about how much water is retained and the impact on yield and quality.

o ADDRESSING A PROBLEM
If there is a problem in the vineyard, it might be that a trial is required to determine the best action. For example, a pest or disease problem could require a trial to determine the best management approach to manage the pest.

o RESPONDING TO A CHANGING ENVIRONMENT
Changes to the physical environment and regulatory environment can facilitate management changes, such as irrigating with less water. A trial can be an excellent way to ensure the new management practice allows yield and quality parameters to be met.

o ASSESSING NEW TECHNOLOGIES
New technologies often confer benefits, but come at a price. A trial provides a method of assessing not only the benefit of new technologies but also to determine if the costs are justified by the benefits.

o COMPARING MULTIPLE PRACTICES
Trials allow multiple practices to be compared under common management so the treatments are directly compared.

Other benefits

In addition to the viticultural management reasons for conducting a trial, there are other benefits to be gained, not the least of which is increased confidence and capability to select and implement new viticultural practices.

Conducting a trial ensures you look at your viticultural business with a critical eye and gives you the ability to look for new improvements.

Many growers who have conducted trials also find new skills develop in the areas of measurement and monitoring. Keeping detailed documentation of your vineyard is a good starting point for implementing any kind of change and is another positive of conducting a trial.

Should I run a trial?

Conducting a trial involves time, energy and in some cases a financial commitment. Before jumping into a trial, it is worth investigating the stages involved in coordinating and running a trial.

Understanding what is involved in a trial and working through the practical considerations will help you determine if a trial is the right option for your business.

The following 13-step process provides an outline of what is involved in a trial:

Step 1: Define the Problem or Opportunity.
Whether you're trying to minimise costs, improve quality or refine management practices, the starting point is working out what you want to achieve.

Step 2: Clarify the Issue.
Once you have determined your issue, it is important to have a clear aim in mind. The clearer and more specific your aim is, the better chance you have of conducting a successful trial that will deliver useful results.

Step 3: Gather Information.
Is there any information available about the type of trial you want to conduct? A good starting point is to search some websites or have a look through grapegrower and winemaker magazines and journals. Local associations and R&D organisations can be another source of information.

Step 4: Potential Cost/Benefit Analysis.
Completing a potential cost/benefit analysis will help you make a decision about running a trial. For example, will the water savings or quality improvements provide you with flow on benefits or is it a matter of long-term sustainability? At this point it is also worthwhile to review the results of your information gathering. If you couldn't find much information about your topic, consider if running your own trial is the best option. Sometimes working with your local association or in conjunction with an R&D provider is the best solution.

Step 5: Experiment Design.
Experimental design is a complex science, and at this stage many people will opt to engage a facilitator to help develop the trial design. This is really important to ensure that your results will be accurate and not misleading. The design will also provide a plan of attack for the coming growing season, with full details including the types of measurements that will be taken and when they need to occur.

Step 6: Identify Your Resources.
How much time and money do you have to spend on the trial? Consider the number of treatments and replicates in the trial. The more treatments you have, the more work that will need to be undertaken. You will also need to work out how much materials will cost (such as mulch, fertiliser, seeds for cover crops, soil moisture probes) and if you will be doing the work yourself or have the budget to employ consultants and casual labour.

It is also worth remembering that because vines are a perennial crop, one year of trials is generally not enough for conclusive results; the recommendation is for three years. Make sure you have enough resources to see the trial to its conclusion.

Step 7: Implement the Trial.
Implementing the trial will be a commitment throughout the growing season. While establishing the trial can take time, sometimes growers forget the trial will add work during the busiest time of the year - at harvest. Make sure you have the ability to implement the trial for the whole season. Again, consultants or short-term staff can be called upon to provide assistance.

Step 8: Data Collection.
During the trial development phase, the types of measurements and frequency will be determined. These need to be carried out during the season. Make sure you have a standard approach to sampling and keep all your records in one place to ensure the data can be crunched at the end of the trial.

Step 9: Statistical Interpretation.
This is probably one of the trickier elements of the trial, and in most cases it is recommended that assistance is provided from a facilitator, consultant or biometrician. These people have the skills to take your data and interpret it correctly and provide you with results that are meaningful and useful.

Step 10: Actual Cost:Benefit Analysis
Although a potential cost:benefit analysis was conducted at the commencement of the project, it is important once the trial has been completed to revisit this and establish if your actual results mirror the projections.

Step 11: Recommendations.
It's time to evaluate the results and see if any of the treatments in the trial have worked and demonstrate best practice. Did the treatments provide the result you were looking for? The results will also indicate if the trial needs to be refined or if any treatments need to be altered.

Step 12: Adoption
If the new practice has met your needs and/or is more sustainable, adoption of the practice should be considered.

Step 13: Validation Trial
If the results are uncertain or the trial needs to be altered, it is worth considering a validation trial. In many cases it is a good idea to run a trial for more than one season, and in fact, most experts recommend a three-year minimum for trials. Keep in mind that a change in season one wil affect the following season and it is best to keep monitoring these changes.

Identifying what kind of trial to conduct

On Farm Trials are based on the principles of action learning that have demonstrated we learn more effectively when we are actively involved in the process. In all agricultural industries, the 'Do Our Own Research' or DOOR model has been developed to allow growers to actively improve their business and crops.

First determine what kind of trial you want to do. Some options include:

- IMPROVING MANAGEMENT PRACTICES
- TESTING VITICULTURAL PRACTICES
- MEASURING THE IMPACT OF CHANGES
- ADDRESSING A PROBLEM
- RESPONDING TO A CHANGING ENVIRONMENT
- ASSESSING NEW TECHNOLOGIES
- COMPARING MULTIPLE PRACTICES

Once you have a 'general' theme or idea about the trial, get specific with what you want to achieve. Make sure you document the aim. For example if you trial a range of irrigation techniques, be specific about the yield and quality parameters you want to achieve.

Some practical considerations to keep in mind are how long it will take to establish the trial, if you have the available time and resources and how long the trial should run.

With some practices, for example those that affect soil organic matter and structure, it can take a long time for changes to occur and differences will not occur in the short-term.

Trials can save a lot of money and problems through choosing the right practice the first time. The downfall is that it might take a few years to identify the most ideal vineyard practice.

What should be measured?

There are numerous measurements that can be conducted during a trial and without doubt taking measurements is one of the most significant components of conducting a trial. The correct measurements can only be selected once the trial objectives have been clearly defined.

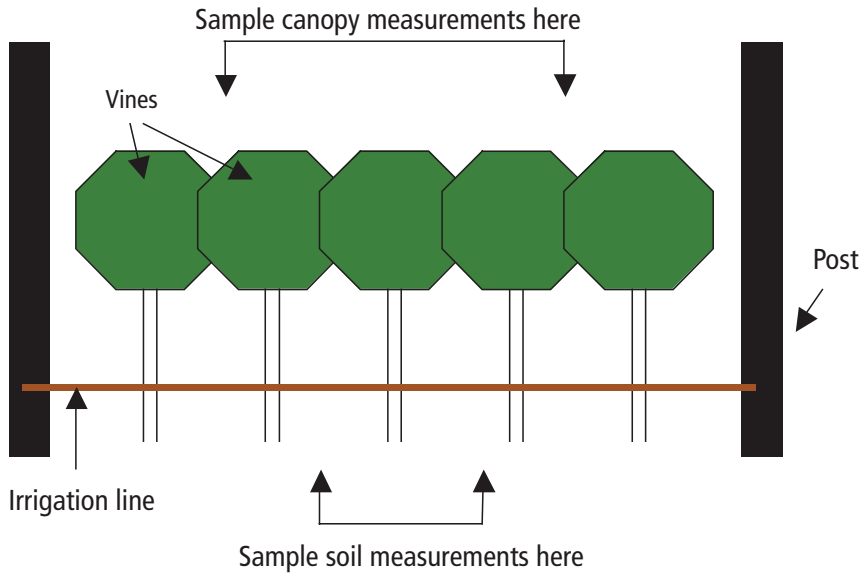
It is important to be objective with your sampling to ensure the integrity of your results.

Here are some tips for sampling:

- It is easiest to work in panels since these are clearly visible units.
- Sample from the middle vines in a panel, except in the case where disease is being assessed.

- Sample from whole vines for petiole analysis, yield and quality parameters, and six shoots per vine for shoot length. When taking soil, earthworm and weed measurements always sample from between two vines in the middle of each panel.
- If taking whole bunches for maturity sampling, increase the plot size for each treatment to three panels and keep 1-2 vines in the middle panel untouched so yield can be assessed at harvest.
- Do not sample from vines that are not representative of the surrounding vines e.g. excessively vigorous, stressed or different age or structure.
- Check each dripper in each of the panels you are using for assessments since maintenance of these drippers can ensure consistency in irrigation applied across the trial.

A diagrammatic explanation of where, within a panel, measurements can be taken.



Some tips for measurements comparing quality effects of a treatment:

- To compare quality it is best to compare treatments at the same baume. If you do not compare at the same baume then you are comparing the ripening speed and this makes it more difficult to make comments on quality differences.
- The logistics of harvesting at separate dates can be difficult so another method of comparing quality is to undertake regular sampling every 3 days starting when one of the treatments reaches within 1.5 baume of the target. Prior to this sampling should be conducted weekly. This regular monitoring allows samples with the most similar baume to be compared for quality, baume, pH and TA being measured on the fresh samples and colour completed on the frozen samples which are most similar in baume.
- To compare juice flavours, bunch samples can be taken at sampling times (as suggested above) and frozen so similar baume juices can be directly compared within the next 3 months.
- To compare wines, it is necessary to harvest at the same baume (aim for within 0.5 baume).

How much time does a trial take?

Every trial is different and will have various time demands. Sampling and measurements will comprise a significant amount of time during the trial and the following table provides an indication of the time involved and level of difficulty for a range of measurements.

Measurements should be chosen from the list depending on the outcomes you are looking to measure in the trial you are conducting. Please note there might be measurements which are specific to your trial which are not included below.

Time

1 = a few minutes per replicate

2 = 15 minutes per replicate

3 = more than 30 minutes per replicate

Difficulty

A = easy, no laboratory skills some basic measurement equipment required

B = some laboratory skills and/or measurement equipment required

C = laboratory skills and/or sophisticated measurement equipment required.

	Measurements	Time*	Difficulty
Quality Measurements	Baumé/ Brix	1	B
	pH	1	B
	Titratable acidity	1	C
	Colour - anthocyanins	2	C
	Yield	2	A
	Bunch number & weight	1	A
	Berry weight	1	A
	Berry sampling	1	A
	Bunch sampling	1	A
	Yield maps - GPS mapped	0	C
Soil Measurements	Soil Variability maps - EM38	0	C
	Soil sampling (shallow)	1	A
	Soil core samples	0	C
	Soil pits	0	C
	Soil temperature	1	A
	Soil moisture monitoring	1	C
	Weed number, coverage & composition	1	A/B
	Earthworms	1	A
	Soil biology/organic matter	1	C
	Root distribution observation	1	A
	Root density	1/2	A/B
	Soil pH	1	B/C
	Soil physical parameters	1	B/C
	Soil nutrient status	1	C
	Soil infiltration	1	B/C
Canopy Measurements	Vine growth stages (phenology)	1	A
	Plant nutrient status	1	C
	Vine vigour - shoot length	3	A
	Pruning weight	2	A
	Trunk Diameter	1	A
	Node number	1/ 2	A
	Shoot number	1 /2	A
	Canopy density - septometer	2	C
	Bud fruitfulness - dissection	2	C
	Lignification - No. shoots with poor lignification	2	A
	Vigour map - NDVI/PCD maps from remote sensing		C
Other Measurements	Daily evaporation and rainfall	1	A/B
	Disease visual assessment - incidence & severity	1	A
	Disease lab assessment (nematode/ latent botrytis)	1	C

Measurement Timelines

Vine growth stages should be recorded when each measurement is taken and rainfall should be recorded daily.
The below tables indicate (by shaded areas) when measurements or samples should be taken.

Measurements etc	Dormancy	Budburst	Shoots 10 cm	Flowering	50% cap-fall
Trunk diameter	yes	yes	yes	yes	yes
Vine Vigour - Shoot length		yes	yes	yes	yes
Pruning weights	yes				
Plant nutrient Status -Petiole analysis				yes	
Shoot number			yes		
Node number	yes				
Canopy density - septometer					
Bud fruitfulness - dissection	yes				
Shoot lignification					yes
Vigour map -remote sensing					
Weed number & cover		yes	yes	yes	
Soil Variability - EM 38 map		yes	yes	yes	
Soil physical parameters		yes	yes	yes	
Soil nutrient status, organic matter, pH, salinity		yes	yes	yes	
Soil water Infiltration		yes	yes	yes	
Soil temperature	yes	yes	yes	yes	yes
Soil moisture		yes	yes	yes	yes
Earthworms	yes	yes	yes		
Soil pits or soil core samples	yes	yes	yes	yes	
Root examination		yes	yes	yes	
Grape yield or Yield monitoring					
Maturity sampling pH, TA, baume					
Bunch number, Bunch weight & Berry weight					
Colour					
Pest or Disease assessment					

Measurement Timelines (Cont.)

Measurements etc	Berry set	Berries pea-size	Veraison	Harvest	Post-harvest
Trunk diameter	yes	yes	yes	yes	yes
Vine Vigour - Shoot length	yes	yes	yes	yes	
Pruning weights					
Plant nutrient Status -Petiole analysis					
Shoot number					
Node number					
Canopy density - septometer			yes	yes	
Bud fruitfulness - dissection					
Shoot lignification			yes	yes	
Vigour map -remote sensing			yes		
Weed number & cover	yes	yes	yes		
Soil Variability - EM 38 map					yes
Soil physical parameters					
Soil nutrient status, organic matter, pH, salinity					yes
Soil water Infiltration					yes
Soil temperature	yes	yes	yes	yes	yes
Soil moisture	yes	yes	yes	yes	
Earthworms					
Soil pits or soil core samples					yes
Root examination				yes	yes
Grape yield or Yield monitoring				yes	
Maturity sampling pH, TA, baume			yes	yes	
Bunch number, Bunch weight & Berry weight			yes	yes	
Colour			yes	yes	
Pest or Disease assessment			yes	yes	

Setting up a trial

Good planning is the best starting point for your trial and its design. Some key things to consider include:

1. Identify what you want to achieve. This is vital since it is very easy to get carried away and sample everything that comes to mind. Determine a specific question, for example: does mulching give better weed control? Collect as much information as is available so you are well informed before starting the trial.

2. Obtain additional information. Good places to start are R&D providers and journals. Determine why this information would be useful to you. Your trial will be more beneficial if it is considered a regional issue and several growers participate.

3. Ask yourself: Are there sufficient economic and/or environmental benefits to justify the trial?

4. What are the possible treatments that could be trialed? Again, only choose as many treatments as are practical and don't forget to include your current normal practice as a treatment - so you have something to compare your new treatments to.

5. Determine what you will need to buy and what you already have available. This is important because it will be used in the cost:benefit prediction to calculate the value of the trial and its results. Also evaluate the time difference for you with respect to the new practice or whether you can make more efficient use of equipment.

6. Determine what measurements you want to take, and how much time you will spend taking them.

7. Consider the effects of vegetation or crops close to your vineyard and only set up trials in the middle of vineyard blocks to overcome a 'border' effect.

Variability

The amount of variability of plants and environmental factors within a vineyard block can have an impact on the success of a trial. If variability is not accounted for, it can obscure the effects of treatments and make treatment comparison difficult. This can lead to mistakes when interpreting results of a trial and may lead to misguided judgements about the best treatments to use on your vineyard.

The concept of variability is fundamental to trials, and it is important to understand the variability that can occur in your vineyard and how to manage it.

Sources of variability within a vineyard block include:

- Soil type and vineyard profile
- Depth of soil
- Irrigation efficiency
- Planting material
- Vine growth and vigour
- Vine yields and fruit condition

Some sources of variability can be controlled, for example, by ensuring all planting material is of the same age, clone and variety, and by having an irrigation system that works efficiently across the trial block. Other variations can be more difficult to control, such as the soil type across a block.

The objective of a viticultural trial is often to measure the effect of different management factors including:

- Irrigation
- Timing of fertiliser or pesticide application
- Compost or mulch
- Rates of lime

It would be logical to expect that the measured differences from the trial may be due to the various treatments applied, but they may also be affected by the variability that exists within the block. The challenge in conducting a successful trial is to be able to separate the influences of treatments from other sources of variability.

Correct choice of a vineyard area for experimentation is critical. The area to be used for trial must be as uniform as is possible, especially in terms of soil type, variety, clone and rootstock. The more uniform the trial area, the less variability there is, and the more likely you are to detect significant treatment differences.

Principles of trial design

Replication

Replication is the application of treatments to more than one independent experimental unit (the experimental unit might be a single vine, suitably buffered, or a panel of vines). Replication allows us to assess the variability at a site and to use this measured variability as a yardstick for determining if an observed treatment difference is more likely to be a real effect (caused by the different action of the treatments), than a chance effect (caused by intrinsic variation in the site). The amount of replication required to ensure a trial has acceptable precision (i.e. a good chance of detecting a pre-specified treatment difference) can be determined by the following formula.

r=18CV2/d2 .....Formula 1

r = number of replicates
CV = Coefficient of Variation
d = treatment difference (as a percentage of the grand mean for the site)

A more technical definition of Formula 1 is that it calculates the number of replicates required to give an experiment an 83.3% probability (5 chances in 6), or "power", of detecting a specified treatment difference d as significant at the 5% level, using a standard statistical test. The CV is a measure of the variability between experimental units that have received the same treatment, relative to the grand mean for the site, and so it is expressed as a percentage.

Below is a table of coefficients of variation (CV) for a variety of characteristics (Table 1) determined by a one-year study of vine characteristics in 13 vineyards (Joyce et al 2003), together with the numbers of replicates needed to detect treatment differences of various magnitudes.

Table 1: Different numbers of replicates (r) to use when planning to detect 20%, 10% and 5% treatment differences for a variety of parameters that can be measured (CVs taken from Joyce et al, 2003).

An example of the calculation used to derive the figures in the table: to observe a 10% treatment difference that is significant using a CV of 5% for Brix, the number of replicates required is:
r = (18 x 52)/102 = 4.5, which is rounded to 5.

	20% treatment difference r =	10% treatment difference r =	5% treatment difference r =
Brix @ CV 5%	1	5	18
Yield @ CV 30%	41	162	648
Circumference of trunk @ CV 13%	8	30	122
Mean Cane weight @ CV 30%	41	162	648
Average Berry weight @ CV 20%	18	72	288
TA @ CV 10%	5	18	72
pH @ CV 4%	1	3	12
Bunch Weight @ CV 12%	7	26	104

The table indicates yield may not be an easy factor to measure (i.e. it has inherent high variability) since it requires a large number of replicates to ensure there is a good chance of detecting a practically important treatment difference. It may be more feasible to use bunch weights as an indicator of yield, and to use 8 replicates to test for treatment differences. Again, for quality parameters, Brix and pH may be more informative parameters to assess, since treatment differences of about 10% of the site mean are likely to be detected using as few as five replicates. The parameter chosen to give an indication of treatment effect should be directly related to the treatment and is important for calculating environmental or economic benefit.

Randomisation

Randomisation is the allocation of treatments to experimental units using chance. Treatments must be allocated randomly within the experimental area to enable us to distribute the variability at the site evenly over treatments and to protect us from accidentally biasing our study in favour of one of the treatments. Random allocation of treatments can be done using a table or list of randomly generated numbers to select the rows and panels where the treatment is to be allocated. In any particular trial, the random allocation does not necessarily guarantee a treatment will not be preferentially allocated to the better or worse areas, but over a series of trials, the allocation will be fair (i.e. unbiased).

Blocking

Ideally, the trial area should be uniform with respect to the likely effect on the variables being used to determine treatment differences. In most vineyard trials, the trial area is less than uniform - there are differences between rows, soil types, watering systems, and so on. However, we can still design a good experiment by adopting the practice of blocking - the grouping together of similar experimental units. Each group of experimental units, or block, is like a "level playing field" that we can utilise for the fair comparison of a set of different treatments. Each treatment is allocated within each block, and so even if the blocks differ considerably, no treatment receives an advantage, and so differences between treatments are assessed fairly.

There is no universal rule on what constitutes a suitable blocking factor in a particular experiment. But in vineyards, blocks are commonly determined by factors such as row, soil type, irrigation line, proximity to roads, etc. The key question to ask is, how can blocks be constructed so that the experimental units are as similar as possible? Note the term "block" has a technical meaning here, which should be distinguished from the broader meaning, as in "the block of vines near my home".

Wise blocking reduces the effect of variability in a trial. Suppose in a fertilizer trial some of the rows of vines are substantially healthier than others, before the treatments are applied. If the treatments are allocated to the experimental units (panels) in a completely random way, the trial will be unbiased, which is good. However, the responses are likely to be highly variable, and part of this variability is caused by the large health differences between the rows, which is unrelated to the treatments. By randomising the treatments to experimental units within each row, the variability can be separated into that which is caused by row differences (which is not of primary interest), and that which is caused by treatment differences (which is of primary interest).

Standard trial designs

It is better to understand the principles of good trial design than to find a standard design and force your trial to fit its categories. However, there are some 'traditional' designs that are commonly used.

Randomised Block Design
As the name suggests this approach takes treatments and sets them out in a randomised approach.

Suppose there are 24 experimental units available for a trial in which we want to compare 4 treatments. There are therefore 6 replicates of the treatments. Assume the experimental units are panels of vines in 6 different rows, and that they are arranged in a 6 _ 4 rectangle as shown in the diagram below, with each cell of the rectangle representing a panel, and each vertical column representing a row of vines. Suppose the rows of vines each have different irrigation lines, and that this may affect the variables being measured.

Block 1	Block 2	Block 3	Block 4	Block 5	Block 6
4	3	1	3	2	1
1	4	2	2	1	4
2	2	4	1	3	2
3	1	3	4	4	3

Figure 1: An example of a randomised block design

In this trial design, each row of vines is a block, and so they are labelled from "Block 1" to "Block 6" in the diagram. Within each block, each treatment occurs exactly once, randomised to one of the experimental units. Each block therefore constitutes a complete replicate of all the treatments, and so for this type of design, blocks are sometimes called "reps".

This design is called a "randomised block design", or sometimes a "randomised complete block design", because each block contains a complete set of treatments. A randomised block design does not have to be arranged in a rectangle, but it must have a complete set of treatments randomised within each block. (If the set of treatments are not complete, the design is called an "incomplete block design".) A randomised block design can have any number of blocks and any number of treatments.

Consider now a situation in which it is necessary to use whole rows as experimental units. This may happen, for example, if the treatments are three different watering systems (A, B and C), each of which can be applied only to an entire row of vines. Suppose here that every second row is set up as a buffer row to allow for the effects of spray drift or water run-off. Suppose that there are 18 rows available for the trial. It is possible to set up a randomised block design with three blocks each with three experimental units, as in the following diagram:

Figure 2: An example of a randomised block design using whole rows

Block 1						Block 2						Block 3				
C		A		B		A		B		C		C		B		A
C		A		B		A		B		C		C		B		A
C		A		B		A		B		C		C		B		A
C		A		B		A		B		C		C		B		A

Latin Square

The randomised block design takes into account one source of local variability, or variability in one direction. Sometimes in the vineyard situation there is more than one identifiable source of variability (for example, topography and soil type), or variability in more than one direction. A trial design, which takes into account two sources of variation, is the Latin square. Instead of referring to blocks, as we do in randomised block designs, we refer to rows and columns. Each intersection of a row and column is a plot or experimental unit. Note that "row" here does not necessarily correspond to a row of vines in a vineyard; it just means a (horizontal) row in the diagram of a trial design. Here is an example of a Latin square with four treatments:

Figure 3: An example of a Latin square design

B	C	A	D
A	B	D	C
D	A	C	B
C	D	B	A

Each treatment appears exactly once in each row and column. A Latin square is therefore only possible if the number of treatments, number of rows, and number of columns are equal. If the number of treatments is a multiple of the number of rows and columns, the design may consist of more than one Latin square. In fact, this is often advisable, because a single Latin square with small numbers of treatments (e.g. 4 _ 4) doesn't usually have enough replicates. A Latin square can be thought of as "blocking in both directions at once", because rows and columns are both blocking factors. If we considered either as a blocking factor on its own, we would have a randomised block design (though the randomisation obviously has restrictions).

Choosing a good design

There often isn't one "right design" or "best design", but there are good designs and not-so-good designs. The name of a design matters little - the issue is whether the principles of experimental design, especially replication, randomisation and blocking, have been applied properly.

If there is just one overwhelming blocking factor (e.g. row of vines) we would exploit that one factor, and, provided there are sufficient experimental units in each block, set up a randomised complete block design. If there are two obvious blocking factors (e.g. soil type and distance along the row from some shelter belt) we might exploit both factors using a Latin square design.

If the number of experimental units within one or more of the blocks is fewer than the number of treatments, we would need to set up an incomplete block design. In addition, if one or more of the rows or columns of a Latin square was missing, we would need to set up an "incomplete Latin square", which is known as a "row-column design." Both of these more advanced designs are not outlined here, as they require substantial statistical expertise.

Without a good design, a trial can be a waste of time and resources. Apply the principles of selecting a good design and also remember that if you get stuck there are consultants and extension officers who can assist.

Data Collection

Within plot measurements
To establish the number of measurements needed from each plot to get sufficiently precise results for each plot, use the following formula:

$n = (t^2 CV^2)/PE^2$ .....Formula 2

n is the number of measurements to be taken on a plot
t is either 1, 2 or 3 depending on whether the chosen level of "confidence" is around 70%, 95% or 99% (we would generally recommend 95% confidence, i.e. t=2)
CV is the within-plot coefficient of variation of the trait to be measured (note this is likely to be different from the between-plot coefficient of variation used in Formula 1)
PE is the percentage error (or half-width of the confidence interval) allowed for a particular measurement (Dunn and Martin, 1998).

Using Brix as an example again, if it has a within-plot CV of 5%, and if the percentage error allowed by wineries is ±5% and one wants to be 99% confident of the result for a plot (t = 3):

$n = (3^2 x 5^2)/5^2 = (9 \times 25)/25 = 9$

Therefore nine measurements or sub-samples are required when a plot is to be measured.

Analysing the results

Although some trials can be relatively simple, the number of questions that arise from trials are considerable, and it can be difficult to find immediate answers. To obtain the full information from the data collected, proper statistical analysis is needed. Simple statistical analyses can be carried out using Excel spreadsheets, but it is best to have the analysis performed by someone experienced in statistics, using a specialist statistical package.