THE UNIVERSITY OF ADELAIDE AUSTRALIA

Herbicide Reduction Strategies for Winegrape Production

FINAL REPORT to

GRAPE AND WINE RESEARCH & DEVELOPMENT CORPORATION

Project Number: **UA 00/1**

Principal Investigator: **Chris Penfold**

Research Organisation: **University of Adelaide**

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HERBICIDE REDUCTION STRATEGIES FOR WINEGRAPE PRODUCTION

Chris Penfold
School of Earth and Environmental Sciences
University of Adelaide
Roseworthy Campus

Ph 08 8303 7735
Email chris.penfold@adelaide.edu.au

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TABLE OF CONTENTS

1. ABSTRACT

The project "Herbicide reduction strategies for winegrape production" aimed to investigate the potential for physical and cultural weed management practices to reduce the requirement for herbicide applications in vineyards. It investigated the capacity for a range of cover crops to compete with weeds, and a variety of mulching materials to inhibit weed germination and growth in the undervine area. The impact of these practices on vine growth, yield and quality varied between the four trial locations, depending on soil type, irrigation and fertigation practices and cropping potential.

Associated work investigated the impact of different cover crop termination practices on summer weed growth, the development of a ribbed roller to lay down cover crops and a sponge wiper for control of weeds in the mid-row and the under-vine area and the water use and competitiveness with weeds of several native species.

2. EXECUTIVE SUMMARY

What is a vineyard weed? This is one of the questions that was asked in the project "Herbicide reduction strategies for winegrape production" funded by growers through the GWRDC. How do weeds differ from sown cover crops, and are there ways these plants can be managed rather than annually being removed with herbicides? Are weeds plants other than those planted in the vineyard, or do they have particular characteristics which make them undesirable – prickles, growth in the canopy, competition for soil moisture and nutrients, or purely nuisance value may be enough to classify a plant as a weed. However, when the full cost of eradication is accounted for, including environmental costs that may be associated with chemical application or cultivation, then the tolerance to plants other than vines in a vineyard may change.

Inevitably however, weeds do exist and need controlling. Are there cost effective options to herbicides for weed control? This project took a four pronged approach to the investigation, namely:

- undervine mulching
- cover cropping
- cover crop termination
- machinery development.

<u>Undervine mulching</u>

Undervine management is the most critical for the health of the vines, as it contains the greatest concentration of vine roots. Conventional weed control involves the creation of a bare strip by using knockdown and residual herbicides or less frequently, cultivation. Environmentally, how benign are these practices though? A bare soil surface is not conducive to good soil structure which has implications for water infiltration. Nor is it conducive to general soil health, including chemical and biological fertility.

If it is accepted that weeds need to be controlled in the under-vine area, then what are the options? Mowing is used quite successfully to reduce the plants leaf area and consequent evapo-transpiration. Steam weeding has now been developed to the stage where it can be used cost effectively in smaller vineyards. There are numerous mechanical devices available which use disc or rotary tillage principles for control. While this equipment can be effective given suitable plant and soil conditions, they are often costly to purchase and require repeat applications. This project focussed instead on the use of mulches to suppress weed emergence, thereby providing longer-term weed control and potentially nutritional benefits as well.

For weed suppression, wheat straw applied to 20 cm depth was most cost effective. Composted products, including recycled organic materials and grape marc, along with grape stems, applied to 7.5 cm depth, were equally effective in weed suppression, but there effectiveness was dependant on the species prevalent at the site and the management of the mid-row. If there was any seed rain from the plants in the mid-row, then the compost provided an ideal medium for seed germination.

Jute matting provided effective control in the two years prior to decomposition.

Compost mulches also provided significant nutritional benefits at some sites, leading to yield increases of up to 50% without a loss in juice quality.

Cover Cropping

The mid-row area often accounts for about 70% of the vineyard floor, and weed management is the principal reason for activities on this area. Cover cropping is now widely practiced, which may be used as a green manure in spring, or less frequently to side throw under the vines as a weed mulch and nutrient source for the vines in an area of greater vine root activity.

The capacity for cover crops to competitive with weeds varies considerably between species. Cereals, especially barley, and to lesser degrees wheat, triticale, rye and oats, are strong competitors. Fodder turnip also displays strong early growth to compete with weeds. Dense stands of medics and sub-clovers generate large amounts of spring biomass, and will compete strongly, particularly in nitrogen deficient soil. Perennial ryegrass and medics/sub-clover were also a very compatible mix for weed control.

In an associated trial, perennial prostrate saltbush and native grasses were investigated for their potential as substitute species for mid-row plantings. Their respective capacities to inhibit weed growth while simultaneously having minimal impact on soil water availability to the vines are the primary assessment criteria at this early stage. Visual observation suggests the three species investigated competed strongly with weeds. Wallaby and windmill grass appear to be using more water than perennial ryegrass, while saltbush is similar. Despite a limited amount of research work with these species and their applicability to vineyards, they are already being used on commercial properties, showing there is interest in enhancing vineyard biodiversity using native species.

The mid-row region therefore needs greater attention paid to how it is utilised, so costs can be minimised and benefits to the vine realised. Suitable cover crops can then be grown which reduce weed growth but simultaneously enhance the vines without costing annually in excess of $100 /ha to sow.

Cover Crop Termination

This trial was designed to answer the question of which is the best way to terminate cover crop growth to reduce summer weed populations. Slashing either solely or followed by herbicide and or cultivation is most commonly used to finish cover crop growth. As an alternative to slashing, where plants are reduced to small particles which break down rapidly, a ribbed roller (see next section) was developed to lay cover crop on the soil surface. This was also compared to a herbicide application and then leaving the crop standing.

Rotary hoeing following slashing enhanced the germination of marshmallow and medics. The other treatments had similar populations. This area of cover crop management requires further investigation, as there is also potential for the selection of cover crop species as competition and suppression for particular weed species. For example, it appears that barley has strong allelopathic potential against wireweed, which can be a major summer weed problem.

Machinery Development

The potential for developing machines specifically suited to vineyards, which were effective, cheap to manufacture and of low maintenance requirements was pursued within a limited budget. As noted previously, a ribbed roller was developed to lay down cover crops, simultaneously creasing the stems to cease growth. This machine was very effective for tall growing cereals, brassicas and weeds, where the soil surface was flat or soft enough to enable the cutting edge to function across the width of the roller. It was relatively cheap to fabricate, and is very low maintenance, so attracted a lot of attention at the field days where it was exhibited.

Glyphosate usage is limited in vineyards to the vines dormant period or the use of covered CDA sprayers in suitable conditions. To enhance the range of application times for this very useful and cheap product, sponge wiper technology from the USA was modified for use in both the mid-rows and under-vine. This machine was very effective at providing selective control based on plant height in a wide range of species while providing drift-free application. Care still needs to be taken that no contact is made with water shoots or pendulous canes, but otherwise the machine was very easy to use and maintain, and received pleasing reviews from those who assessed it.

In conclusion, this project has shown that it is possible to reduce herbicide use (and cultivations) in vineyards. Managers firstly need to reassess what a weed is in a vineyard and what is the purpose of the mid-row, then manage accordingly so cost-effective benefits can be provided to the vine and the vineyard floor. However, further work is required in developing improved management of summer weeds, in further assessing the potential of native perennial grasses and saltbushes and developing improved seeding techniques for these species, and in better management of the under-vine area, so soil health is enhanced with consequent benefits to vine yield and quality.

3. BACKGROUND

Grape production systems in Australia are by world standards of low chemical input. However, in an industry so market driven as wine, there is no room for complacency. European and Japanese markets are becoming increasingly sensitive to chemical usage in food and beverage production, requiring vignerons to pursue best practice management based on low pesticide input. The threat of herbicide resistant weeds, and the potential for on and off-farm pollution all increase the need for technological solutions which are ecologically and economically sound. Weed control in vineyards, when poorly managed, has the potential to be very expensive, environmentally damaging and detrimental to vine productivity and grape quality.

The project “Herbicide Reduction Strategies for Winegrape Production” was aimed at the development of non-chemical or reduced chemical weed management systems to provide both organic and conventional growers with a broader spectrum of opportunities for weed control. This was designed to assist the wine industry in achieving goals of reduced chemical application and in meeting environmental requirements that would consolidate the ‘clean and green’ image of the industry.

4. PROJECT AIMS AND PERFORMANCE TARGETS

Aims:

- To develop stable, robust weed management systems with reduced reliance on herbicides, for a range of agroclimatic zones
- To integrate weed management in a systems approach with vineyard management, incorporating the needs of water, nutrient, pest and disease management with production economics.
- To provide a package of weed control strategies that will enable both conventional and organic producers to either minimise or negate their herbicide requirements, without compromising either grape yield or quality.

The following outputs and performance targets were originally suggested:

Outputs	Performance Targets
1. Established grower groups	A grower group consisting of 10 members established for each trial site by March 2001.
2. Weed inventory	For each site develop a weed inventory by May 2001.
3. Literature review	Review the literature on the individual weed species, to determine their biology, ecology and management options, by June, 2001.
4. Establish trials	By July, 2001 and 2002, have planned and implemented trials at a minimum of five sites.
5. Progress report	By July 13, 2001, provide the corporation with a progress report and statement of receipts and expenditure.
6. Harvested trials	By May of 2002 and 2003, trials will be harvested and the fruit assessed for yield and quality.
7. Extend information	By December, 2002, field days will have been conducted at least once at each site, articles will have been published in industry magazines, and further extension undertaken where possible.
8.Continuing project submission	Submit application for project continuation by December 15, 2001and 2002.
9. Final report	By the 28th of September, 2003, the final report will be submitted to the GWRDC.

In addition to the above, new research directions proposed in 2002 led to the following:

Outputs (for 2002/2003)	Performance Target (for 2002/2003)
1.Water use and weed suppression trial	1. By December 2002, establish a replicated trial at Roseworthy investigating the relative water use of a range of native perennial species which will provide weed suppression in the mid row.
2.Inter-vine herbicide applicator development	2. By July, 2002, develop an effective sponge wiping mechanism for safe, efficient, low cost non-selective herbicide application along the vine row.

The balance of this report will describe the methodology and outcomes of this project.

5. METHODS

This project involved four principle components, as listed below:

The design and implementation of on-farm trials

The design, manufacture and assessment of new equipment

The preliminary investigation of native perennials as suitable cover crops.

The delivery of outcomes to industry.

5.1 The design and implementation of on-farm trials

5.1.1 Background

Weed management in vineyards is based on the management of two distinct areas – the mid-row and the undervine area. To provide long-term control of weeds in both areas, it was necessary to investigate practices other than conventional knockdown techniques based on herbicides. A range of environments was also required in order to cover different weed spectrums, soil types and rainfall / irrigation regimes.

5.1.2 Trial Sites

Four off campus sites were chosen to provide the environmental diversity required for this project to be relevant to a large group of growers. The site characteristics are shown in table 1. The trial sites were located at:

Clare – Southcorp vineyard

Kingston on Murray – BRL Hardy's Banrock Station

Langhorne Creek – Rosemount Wines

Barossa Valley – Ann Wells

Roseworthy Campus

Table 1: The principal characteristics of each trial site are shown below.

Site	**Varieties**	**Soil type**	**Rainfall (Ave.)**	**Dominant weed species**
Clare	Chardonnay Merlot	Dark grey brown fine sandy clay loam	634	Capeweed, wireweed, brome grass, milk thistle
Kingston on Murray	Chardonnay	Dark brown loamy fine sand	244	Long fruited turnip, wireweed, milk thistle, caltrop (in summer)
Langhorne Creek	Cabernet sauvignon	Dark brownish grey fine sandy clay loam	383	Blackberry nightshade, silverleaf nightshade, wild radish
Tanunda	Shiraz Cabernet sauvignon	Dark brownish grey fine sandy clay loam	547	Capeweed, ryegrass, bromegrass, wireweed
Roseworthy	No vines	Dark brownish grey fine sandy	446	Wireweed, capeweed, ryegrass.

		clay loam		

5.1.3 Trial designs

At each off-campus site, two experiments were established in 2001. Both experiments were designed in consultation with biometricians to ensure statistical robustness. The trials were:

5.1.3.1 Determination of the ability of a range of cover crop species to constrain weed growth and to examine the impact of the cover crops on vine nutrition, growth and yield.

The cover crops included annual pasture legumes and grasses which were expected to regenerate each year, perennial ryegrass and a green manure crop. Species were chosen specifically for each site according to soil type and rainfall. Where possible, cultivars with resistance to insect pests such as red-legged earth mite were also chosen.

The trial was established in a randomised block design of 5 treatments replicated five times, with each plot covering 2 panels. The cover crop was sown on both sides of the vines from which measurements were to be taken. The control plots received the same tillage as other treatments, but no seed was sown.

Assessment:

Crop vs weed biomass production:

In spring of both years, biomass cuts using a 0.1 m^2 quadrat (2 per plot) were sampled and sorted to crop and non-crop species, oven dried and weighed.

Vine petiole and leaf blade total N content:

Nitrogen, in its nitrate form, is highly mobile in the soil, and readily taken up by the vines root system. Using this characteristic of nitrogen, petiole samples from the vines adjacent to the high legume component treatments and the control plots with no legumes were analysed in 2001 and 2002. Petioles were sampled at 50% capfall and leaf blades at harvest, dried at 40^0C, ground and analysed for total N using Complete Combustion Gas Chromotography at Waite Analytical Services.

Yield and quality (baume, pH, TA, colour):

Plots (excluding buffers) were hand-harvested, grapes were weighed on-site, and samples were then sent to company laboratories for quality assessment. Colour analysis of red grapes was performed at the AWRI laboratories.

Table 2: Cover crop allocation over the four trial sites, 2001/02.

Cover crop used	Banrock Station	Clare	Langhorne Creek	Barossa Valley
Cereal rye/barley / legume green manure	Year 1	Year 1	Year 1	Year 1
Fodder turnip	Year 2	Year 2	Year 2	Year 2
Medic /annual ryegrass	✓		✓	✓
Sub-clover / annual ryegrass		✓		
Perennial ryegrass		✓	✓	✓

Note: The cultivars used at each site are shown in Appendix 1.

5.1.3.2 Determination of the ability of a range of mulching materials applied to the undervine area to suppress weed establishment, and their subsequent impact on soil chemistry, vine growth, yield and grape quality.

The mulching materials utilised in the trial were commercially available products. All materials were applied to a row width of 60 cms. Plots were 2 panels in length with 6 vines in total, giving a plot length of 9 – 12 metres, depending on vine spacing. A Latin square trial design was used, so the trial extended over 5 or 6 rows (Banrock), with each treatment represented in each row.

The products used and there application rates were:

1. Jute matting, 800 gm/m^2 density, laid on the soil surface and cut to fit around the vine trunks and posts.
2. Recycled organics compost, referred to as Nitramulch (Peats Soils) or Jeffries Compost. This was applied to a 75mm depth.
3. Grape marc compost, produced by Peats Soils, made from grape marc and animal manures composted simultaneously, applied 75mm deep.
4. Wheat straw, applied 200 mm deep.
5. Grape stalks, a winery waste product from the de-stemming process. These were applied at 75mm deep.

All experiments included a nil treatment control, which was treated in accordance with standard vineyard practice – that is sprayed or mechanically weeded.

Assessment:

Weed populations and biomass: where the populations were small, weeds were counted along the entire plot length excepting the buffers. Alternatively, biomass cuts (2* 0.5 m^2 / plot) were taken.

Soil chemistry: prior to implementation of the trial, soil samples (3 / plot) to 15 cms deep were taken, oven dried at 40^0C, and stored. This was repeated at the conclusion of the trial, and all samples were analysed for total N, ammonium N, P, S, organic carbon, Fe, EC, pH (CaCl), pH (H_2O), texture and colour. The change from antecedent to new levels was calculated and statistically analysed.

Vine nutrition: Vine petioles were sampled at 50% capfall and treated as per section 5.1.3.1.

Grape quality: As per 5.1.3.1.

The mulch treatments applied at the four sites are shown below.

Table 3: Mulch materials and their site of application.

Mulching Material	Banrock Station	Clare	Langhorne Creek	Barossa Valley
Jute matting	✓	✓	✓	✓
Straw	✓	✓	✓	✓
Green organics compost	✓	✓	✓	✓

Green organics mulch		✓		✓
Grape marc compost	✓		✓	
Grape stalks	✓			

5.1.3.3. Cover crop Management - Roseworthy Trials

Methodology

Year 2002

To determine the effect of cover crop management on summer weed growth, a range of cover crops were sown then treated in spring by either rolling, slashing, slashing and rotary hoeing or left standing. Assessment of this trial was through plant counts and biomass production of wireweed (*Polygonum aviculare*) during the summer period.

Four cover crops, involving a range of species, were sown in a randomised complete block design with four relications. The cover crops used were:

1. barley/medic green manure mix
2. medic/ryegrass mix
3. fodder turnip
4. perennial ryegrass
5. control

Biomass sampling and weed populations were determined through dry matter cuts (15-3-02).

Year 2003.

In year 1 there appeared to be a strong allelopathic impact from barley on wireweed. To determine if this was influenced by cover crop management, a crop of Mundah barley was sown, and the same treatments were imposed at grain fill stage of crop maturity. Termination treatments were applied at early grain fill (9-10-02), by which time the barley had generated 4.9 t/ha of biomass. The treatments applied were:

1. weed wiper using glyphosate residue left standing
2. layed down on the soil surface with a ribbed roller
3. mulch with Silvan mulching mower
4. mulch and rotary hoe.

Weed counts and biomass production were determined on 13-5-03.

5.2 The design, manufacture and assessment of new equipment

The termination of cover crop growth in spring generally involves slashing or mowing, then either spraying the regrowth with a broad-spectrum herbicide or using cultivation. Mowing breaks the cover crop up into very small pieces which decompose quickly, providing little mulching benefit for weed suppression or moisture conservation. Other downsides of these techniques are the additional mid-row traffic, cost in time, energy, maintenance and herbicide. Herbicide application is seen as the more environmentally benign approach to weed control because it prevents the need for tillage. To overcome some apparent gaps in equipment now used by growers for terminating cover crops and applying herbicides, two new pieces of machinery were designed and manufactured. These were a ribbed roller and a sponge wiper mounted on the front of a four wheel ATV. With additional funding from GWRDC in 2002, an under-vine version of the sponge wiper was also developed.

In addition, a Bezzerides under-vine weeder was donated to the project by the Californian company and was evaluated by several growers.

5.3. The preliminary investigation of native perennials as suitable cover crops.

In spring of 2002, an extinct water use site which was already equipped with neutron probe access tubes, was planted to 7 native perennial species. The trial design enabled 3 replicates of each treatment.

The site was initially irrigated by soaker hose to enable plant establishment. This ceased at the beginning of September, and soil water measurements using a neutron probe commenced at the end of September, and were conducted monthly until April. Biomass cuts were taken in mid-December to determine weed vs treatment differences in productivity.

Table 4: Perennial species used to determine comparative water use and weed competitiveness, Roseworthy, 2002/3.

Scientific name	**Common Name**
Atriplex semibaccata	creeping saltbush
Chloris truncata	Windmill grass
Myoporum	
Phyla nodiflora	Lippia
Dichondra microlata	Tom thumb
perennial ryegrass	
Danthonia linkei	Wallaby grass
Control	Bare soil

5.4. The delivery of outcomes to industry.

The delivery of results to industry through the wine industry press and speaking at conferences, seminars and workshops has been a significant part of this project. The articles written and presentations made are listed in Appendix 1.

6. RESULTS AND DISCUSSION

The vineyard floor consists of two discreet areas namely the undervine and mid-row. This section will address the outcomes of the trials dedicated to these zones of the vineyard floor.

6.1 Undervine

6.1.1 Weed control.

The trial sites displayed considerable differences in weed pressure. The capacity of the applied treatments to smother weed growth was tested differently by the species present. However, at all sites there were significant reductions in weed populations from the application of all mulching materials in the first year. Their value in weed suppression then altered in the second year depending on the weed control in the under-vine area and the mid-row in the first year. Where seed rain occurred onto the mulch, germination and growth in the second year were considerable, particularly on the jute and compost treatments. This was particularly evident at the Barossa site (Fig 1).

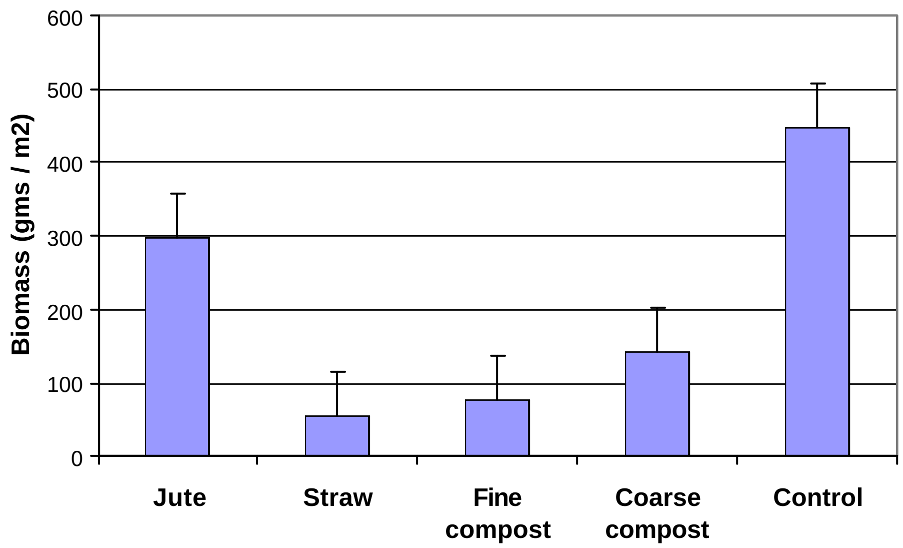


Figure 1: Weed biomass in the undervine area, Barossa, 31-10-02

The performance of the individual products as weed suppressing agents is discussed further below.

Jute matting

Jute matting was included in the trial as it was expected to provide a biodegradable mulching material suitable for use in establishing a new vineyard. It was applied in 60 cm wide strips of 800 gm/m^2 density material, which is approximately 8mm thick. It was rolled out in a continuous length along the row, and cuts were placed at each vine trunk so it fitted neatly. Jute in the first year provided very good control of most plants, excepting nightshade at Langhorne Creek. However, its steady decomposition through the summer and autumn period compromised its value as a weed mat over the second season. Its use is therefore not recommended for use in either new or established plantings for reasons of application cost, problems with handling and its period of efficacy.

Cereal straw

Wheat straw applied 20 cm deep proved to be a very effective smothering agent. However, at Langhorne Creek, the *Solonacea spp* (silverleaf and blackberry nightshade) had sufficient energy to emerge through it. The need for caution when importing the product onto the property was apparent at Banrock Station, where in the first year a prolific stand of wheat was produced in the straw via seed contained in it (see Fig 2). Fortunately this was an innocuous "weed" with a short seed bank life and was readily sprayed out, but some herbicide resistant species are not so amenable. Where weed control is the main reason for undervine mulching, and where soil nutrition is not limiting vine performance, the results of this trial would recommend the use of clean wheat or triticale cereal straw as an undervine mulch. In most years it is also readily available for a reasonable price, and the spreading is now mechanised and efficient.

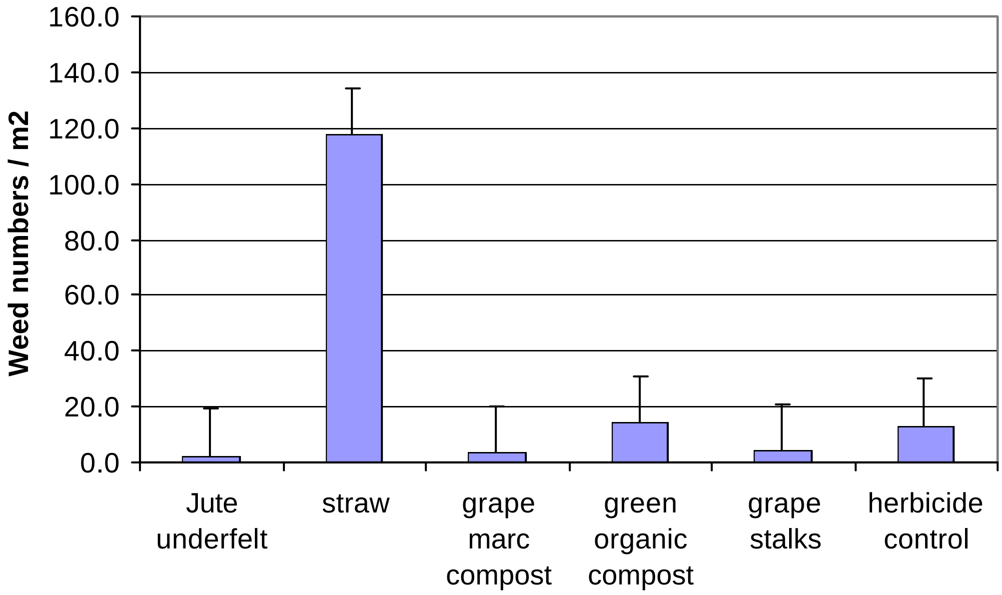


Figure 2: Banrock Station weed numbers, October, 2001

Grape marc compost, green organic compost and forest mulch.

In 2001 when this project was established, there was an issue with the disposal of winery grape marc. Composting the marc was undertaken to add value to this product and provide a source of organic compost available for use in vineyards and other intensive agriculture. This product was used in the experiments at Banrock Station and Langhorne Creek.

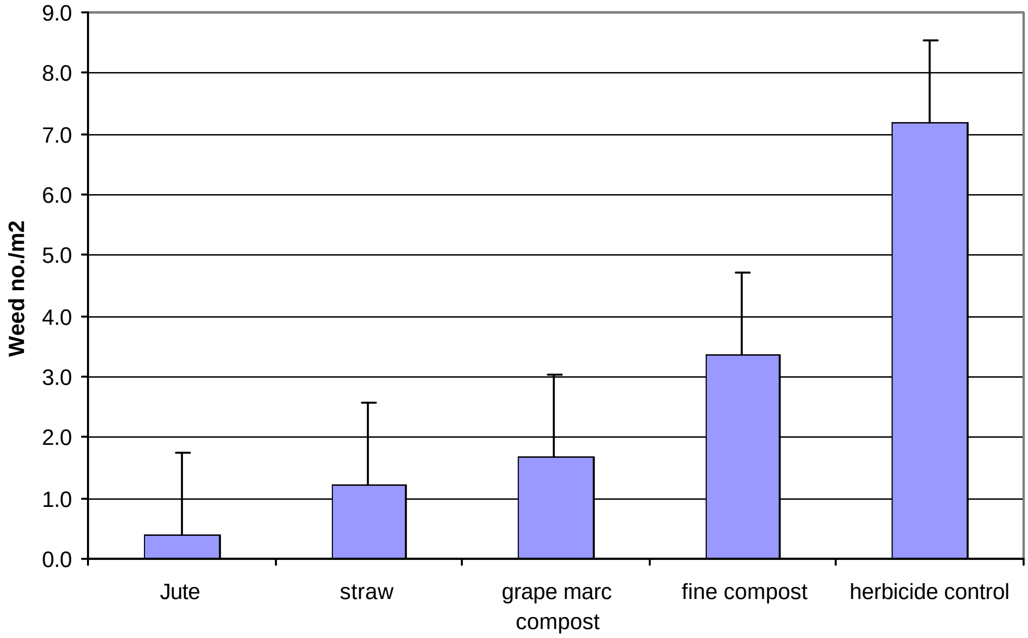


Figure 3. Weed populations, Langhorne Creek, February 2002.

As shown in figure 3, the grape marc compost provided better control of weeds than finely sieved green organics compost. It also showed a greater capacity for inhibition of nightshade over the summer period, and grasses over the winter period, while at Banrock Station during the winter period, turnip weed emergence was suppressed more effectively by the grape marc based compost. The population differences are also significant to the extent that further weed control would be expected where the fine compost has been applied but it would be difficult to justify at only 1.7 plants / m^2 as shown at Langhorne Creek.

The difference in efficacy is possibly explained by the tannins contained in the grape marc, which are suspected of having allelopathic qualities (Kalburtji, 2001).

The level of weed suppression provided by the fine organic compost was dependent on the weed species present. At the Barossa site, the principle weeds were grasses, and their emergence was controlled by this product. Larger seeded broadleaf weeds at the other sites were not controlled, suggesting the possibility of germination inhibitors contained in the marc, and maybe an increase in energy requirement as shown in the larger seeded broadleaf weeds to emerge through products with a coarser composition such as grape marc and forest mulch products.

Grape Stalks

Banrock Station was the only site where this product was investigated. Grape stalks are another winery waste product and were being used on the Banrock vineyard as an undervine mulch, so they were included in the trial as a vineyard best practice control.

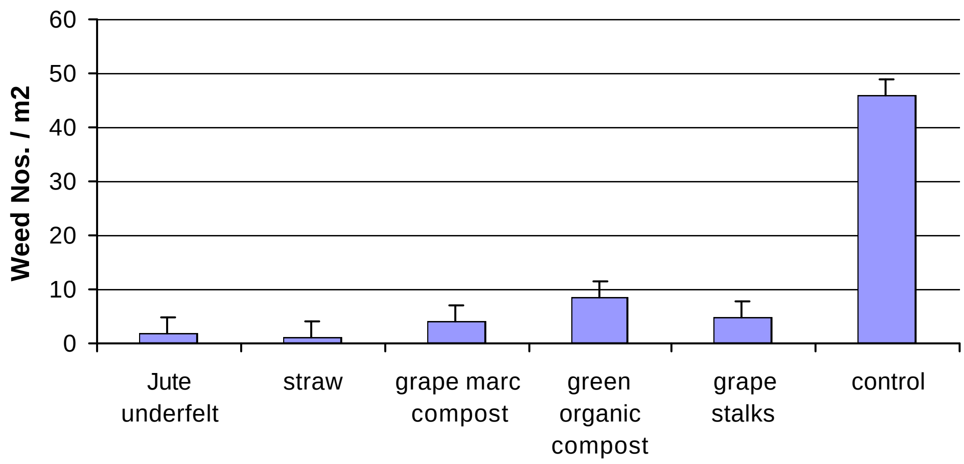


Figure 4: Weed populations, Banrock Station, 11-9-02

Despite the grape stalks only being applied to 7.5 cms. deep, which is about half that used by Banrock management, they were as effective as the other treatments at containing weed growth, as shown in figure 4. The cheap nature of this product, low transport cost and efficacy compared to other products, would suggest this to be the preferred product for cost effective weed suppression in the Riverland region.

6.1.2 Yield and Quality

The impact of mulches on grape yield has been reported frequently (eg. Buckerfield, 2001), but the range of mulches under investigation in this trial have not been previously been compared for yield and quality benefits at the same site.

Langhorne Creek

This site proved to be highly yield responsive to the addition of compost mulches. Significant yield increases were recorded in 2002 and 2003, with a 50% increase observed in 2003 with the use of green organic material, as shown in figure 6 below. The reasons for this increase are a combination of greater water availability through less weed growth and the reduced evaporation due to mulch application, and the nutrient benefit of the compost compared to cereal straw. The nutritional benefits of the mulches are discussed further in section 6.1.3.

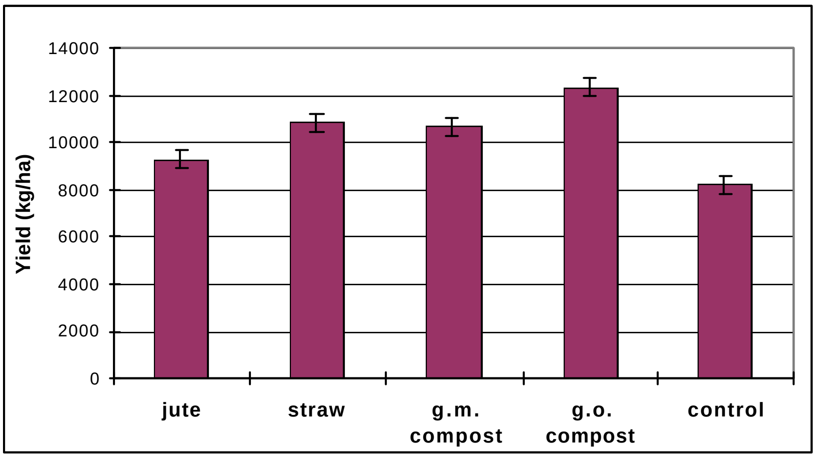


Figure 5: Grape yields, Langhorne Creek, 2003(LSD = 806)

Must quality was also affected by the mulching treatments. Figure 6 shows a slight but significant decrease in Baume and pH from mulching with straw and increases in TA through straw and green organics compost application.

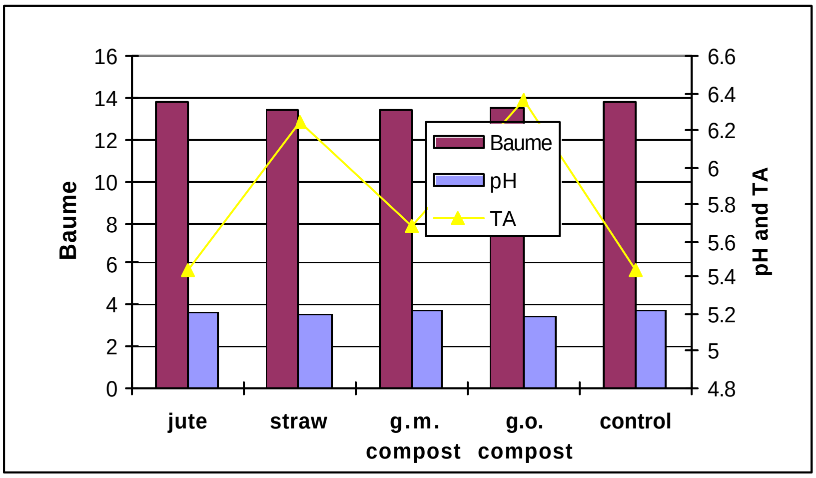


Figure 6: Must quality characteristics, Langhorne Creek mulching trial, 2003 (LSD's: Baume 0.28; pH 0.1; TA 0.67

The yield increases recorded were impressive, and would readily pay for the material and spreading costs in the first year. While quality differences were recorded, it is unclear whether these would be recognised as significant by winemakers.

Clare.

The 2002 harvest was low yielding, and showed no significant treatment differences. This may have been due to the September application of the mulches, providing a limited time period for the uptake of available nutrients into the vine.

The 2003 harvest was better, and treatment differences became evident, as shown in Figure 7.

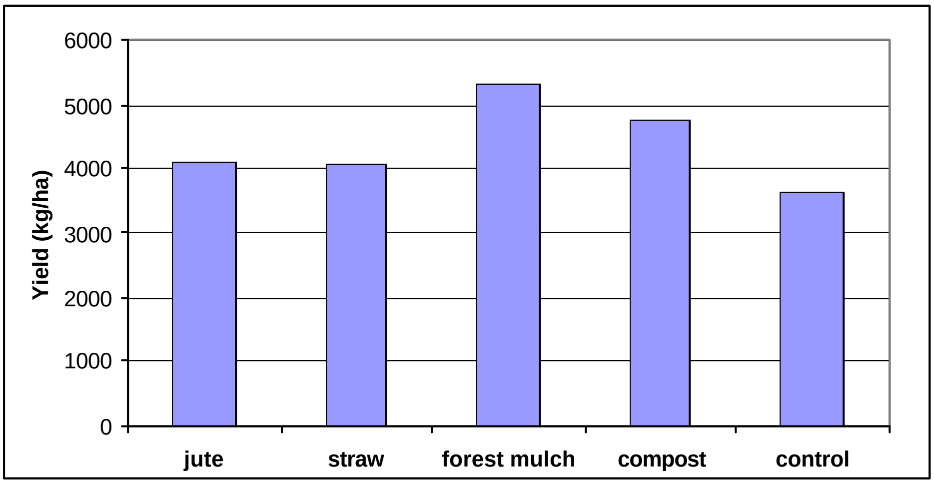


Figure 7: The impact of a range of mulching materials on grape yield, Clare 2003 (LSD = 1025)

In this season, both the forest mulch and the compost achieved significantly higher yields than the control. The reasons for the yield increase are a combination of improved soil moisture status and nutritional benefits generated by the mulches, which are discussed further in section 6.1.3.
Quality analysis over both years showed no significant difference between any treatments.

Banrock Station
Grape yields at Banrock Station showed no treatment differences in either year, despite a significant increase in petiole N where green organic compost was applied. This outcome is most likely explained by the masking of any nutrient or soil moisture conserving benefit of the mulches by the large water applications used in this region, together with fertigation to supply optimal nutrient supply to the vines. The water conservation achieved through mulching is small compared to the quantity of water applied (> 5 ML/ha), preventing treatment differences to be apparent. With all the vines nutrient requirements also supplied through the irrigation system, there is no benefit in additional nutrients being provided in the composts. The grape stalk mulch presently being used on this property provides similar reductions in weed growth to the other treatments, without any yield suppression, and is sourced locally so it is much more cost-effective than other mulches used on this site.

The acid profiles of the must showed a small but significant increase in pH (0.031 and 0.082 pH units respectively) where grape marc compost and grape stalks were applied, which correlates with the increased levels of soil potassium observed under these treatments. The importance of this pH increase from a winemaking perspective has not been determined, but it should be monitored over the longer term to ensure the addition of grape stalks in this environment is not adverse to quality specifications

Barossa
The site selected for the undervine mulching trial displayed a high degree of variability within the vines, preventing the collection of meaningful yield data. Grape berries were sampled for quality assessment, and showed greater colour development following the application of jute, compost and forest mulch. Berry colour is influenced by factors such as nitrogen

content and consequent skin thickness, berry size (Dahnburg, pers. comm.), and fruit exposure to light (Smart and Robinson, 1993). It is often suggested that these requirements are more readily met by fruit from lower yielding vines, but as Campbell noted in Smart (1993), the best wines came from higher yielding vines. This may well be due to a better balance of soil nutrients, supporting the outcome from this site, that the vines fertilised with compost produced better colour characteristics.

6.1.3 Pruning weights and shoot numbers

Pruning weights and shoot numbers were determined at the Clare and Langhorne Creek sites. They were not done at the Kingston-on-Murray site because it was a minimally pruned vineyard, and the Barossa site again contained too much variability between vines. The results for pruning weights are shown below. Shoot numbers were not significantly different at either site.

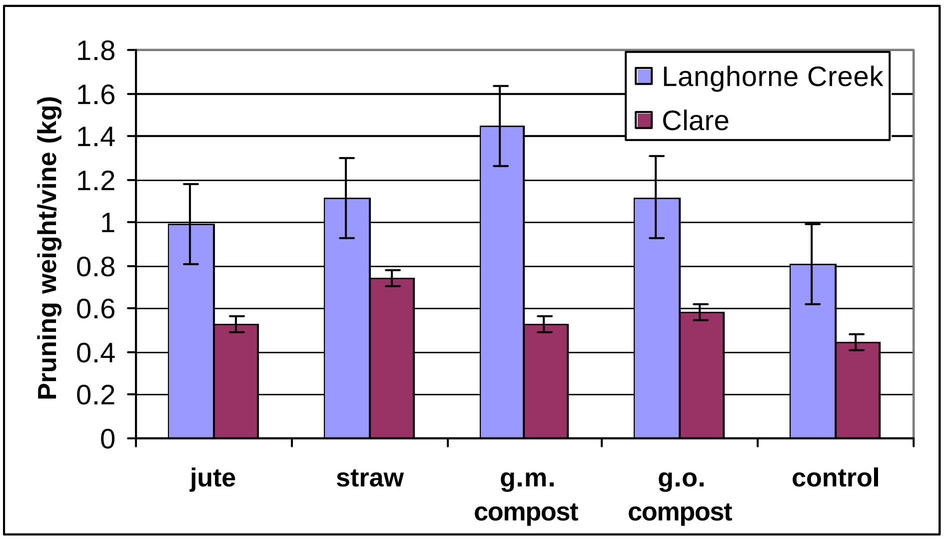


Figure 8: Pruning weights for the undervine mulching trials, Clare and Langhorne Creek trials sites, 2003.

The r^2 value for pruning weights and yield was 0.61 for Langhorne Creek and 0.05 for Clare, indicating for the latter site that other factors such as bunch and berry numbers and size were the primary reason for yield differences. However, there were no significant differences in these parameters either. At Langhorne Creek the shoots were heavier and there was a very strong ($r^2 = 0.87$) correlation between yield and bunch number, indicating a change, possibly to soil moisture or nutrition, initiated an increase in bunch number the previous season. Work by Skinner and Mathews reported in Coombe and Dry (1992) by Robinson refers to low bunch numbers being attributed to restricted phosphorus supply. Table 5 shows a significant increase in soil P associated with grape marc application but the highest yield came from the green organics compost treatment. The impacts on yield and pruning weights are therefore most likely from a combination of elements rather than any one in isolation.

6.1.4 Soil chemistry:

During the 2 year period of the trial, some very significant changes to the soils nutritional status occurred, which in some cases was influential on grape yield, sugar contents and acid balance. The outcome of chemical analysis performed on soil sampled before mulching and after 21 months are shown below.

Table 5: The significant changes in soil chemistry, expressed as a percentage, from 2001 to 2003. Those treatments which are significantly different (0.05%) are shaded

Treatment										
Clare	**N**	**NH4**	**P**	**K**	**S**	**OC**	**Fe**	**EC**	**pH CaCl**	**pH H2O**
jute	5			5	40					5
straw	-71			37	19					9
forest mulch	-71			34	20					11
compost	-25			155	114					16
control	-25			12	90					2
Langhorne Ck										
jute	-64		0	-20					3.8	-0.4
straw	-14		62	11					1.4	5.8
grape marc	-11		295	338					6.8	5.8
compost	188		37	120					3.4	-2
control	-35		6	-10					4.2	-0.2
Banrock										
jute			-2	-30				57		
straw			1.5	-9				57		
grape marc			63	147				187		
compost			2.7	63				116		
grape stalks			-18	124				74		
control			-16	-22				27		
Barossa										
jute				63	-6			-8	3	6
straw				136	-23			0	3	9
forest mulch				220	-26			1	10	17
compost				329	103			140	10	16
control				88	-40			-13	3	8

An important outcome of this work is that it expanded the information base about the impact of mulches on weeds and productivity from the previous trials of Buckerfield and Webster. This project applied the mulches in other environments which had not previously been assessed. This is discussed below, based around some important soil parameters that were analysed.

Nitrogen: At the Clare site, soil N levels decreased under the straw and forest mulch compost product, and increased significantly at Langhorne Creek where compost was applied. The Banrock and Barossa sites displayed no significant change to soil N. The nitrogen contents of the mulching materials ranged from 2.5% for grape marc compost to 1.1% for the forest mulch product. According to Wilkinson (2003), (Wilkinson and Bialla, 2001), composts need to have an N content greater than about 1.5% to supply significant amounts of N. The grape marc products, despite having the highest N content, had no significant impact on soil N at the two sites where it was applied. By contrast, green organic compost applied at Langhorne Creek resulted in a 188% increase in soil N compared with the control. This outcome would normally be treated with suspicion, but it correlates well with the yield increase (fig 5) also shown at this site. The reason for this discrepancy in compost efficacy between sites is possibly due to the increased frequency of irrigation and quantity of water applied, enabling greater mineralisation of the organic nitrogen and increasing its availability to the vines.

At Banrock, it is likely the nitrogen was either utilised by the vines or leached through the coarsely textured soil, resulting in no change from the control treatment.

The Barossa and Clare sites displayed no change in soil or petiole N, but the Barossa soil was sufficiently buffered and N use by the young vines was low, so deficiencies in N through the high C:N mulches (straw and forest mulch) did not occur.

Phosphorus: The grape marc compost contained in excess of 0.5% P, and at both sites where it was applied (Langhorne Creek and Banrock Station), a significant increase in soil P occurred.

Potassium: The recycled organic composts contained approximately 3% potassium, and generated up to 330% increase in soil K over the two year period of the trial. The grape marc compost had a similar effect at all sites except Clare and grape stalks were also effective at raising K levels at Banrock.

There have been concerns raised about the use of composted products which have high available K contents and their potential impact on grape juice quality through raised pH (Agnew et al, 2003). Results from this trial would support the hypothesis of Agnew et al, that grape vines have the capacity to regulate the rate of potassium uptake and therefore have no detrimental effect on berry pH. This was determined by berry analysis at harvest. Of the sites used in this trial program, the Langhorne Creek site provided the most spectacular responses to the mulching treatments. Grape marc compost, which raised soil potassium by 338% (see Table 5), and significantly increased petiole potassium, did not create an increase in must pH (figure 6).

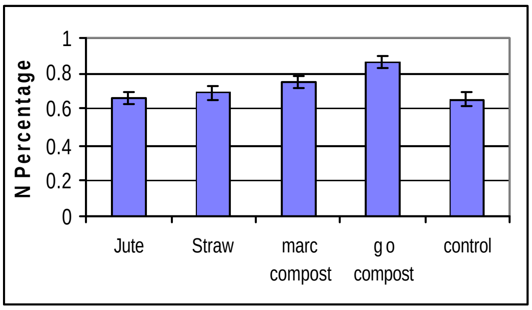
Electrical conductivity: At Banrock, all treatments resulted in increased EC's, with the composted grape marc and green organics being significantly greater than the control. A possible explanation for this lies in the capacity of mulches to prevent water from reaching the soil, particularly in the case of small rainfall events. The 2002 year was a drought in the Riverland region, and the leaching of salts which may normally have occurred with rainfall over the winter period may have been prevented or reduced by the mulches applied over the surface. However, the soil salinity at all sites is low (Hunt and Gilkes, 1992) and would not be impacting on productivity.

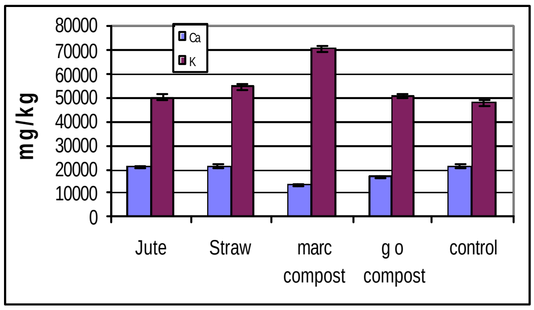
pH: The compost products, with pH levels ranging from 7 – 8.2, led to significant increases in soil pH at all sites except Banrock Station. The 10% rise in pH found at the Barossa site represents a 0.5 unit rise, but the level remains in the pH neutral level. At the Banrock site, where the pH ($CaCl_2$) is 7.9 and therefore similar to the most alkaline compost, the soil was strongly buffered against any further rise. By contrast, the Clare site antecedent pH ($CaCl_2$) was 4.86, and by 2003 this had risen 0.5 units on the composted treatments. The compost is therefore providing a valuable liming effect on acidic soils, but it would be seen as detrimental to nutrient balance to have them increase the pH beyond neutral on soils such as those in the Barossa.

6.1.5 Vine Nutrition

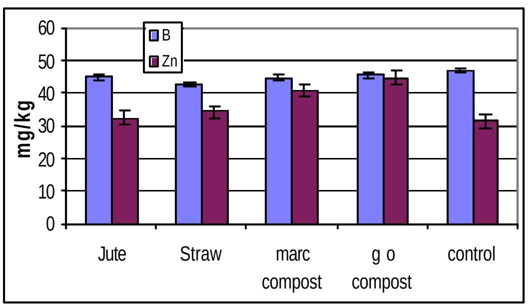
It is difficult to realize the investment in undervine mulching purely on the reduced requirement for herbicides over the lifetime of the mulching material. Other benefits such as improved vine nutrition or soil moisture conservation may result in higher yields and thereby repay the cost of mulching. As shown above, at the Clare and Langhorne Creek sites, mulching with the compost products generated significant yield increases. Improved nutrition for the vines is likely to be one factor creating the improvement in yield. The nutritional differences between treatments were determined through analysis of vine petioles and leaf blades.

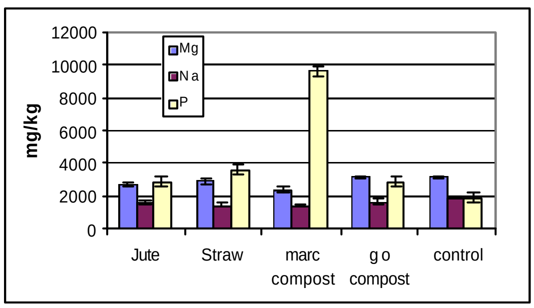
The results from Langhorne Creek are shown below, and for the other sites, in Appendix 5.4 – 5.6.





(a) (b)





(c) (d)

Figure 9: Vine petiole analysis, Langhorne Creek, 2002, for (a) nitrogen (b) calcium and potassium, (c) boron and zinc and (d) magnesium, sodium and phosphorus.

The petiole analysis results mostly mirror the changes measured in soil nutrition, shown in Table 5. For the two sites where yield differences were evident, nutrient concentrations in petioles provide justification for the yield differences. At Langhorne Creek, increased nitrogen, zinc and phosphorus were evident, but the only element recognised as deficient was nitrogen. These results would therefore confirm the benefits of the use of the composted products to raise soil nitrogen levels, while simultaneously providing a balance of other nutrients and improved soil moisture status to provide a yield benefit.

The information provided in figure 10 shows the inter-relationship between soil moisture, nutrition and yield. Soil data showed the composts suppressed the soil nitrogen status over the three year period, but this may have been through vine uptake rather than depletion induced by the compost having a high C:N ratio. It is therefore predicted that on the compost treatments, through improved soil moisture status, organic matter mineralisation has occurred, and this nitrogen has been taken up by the vine, improving vegetative growth and increasing bunch numbers.

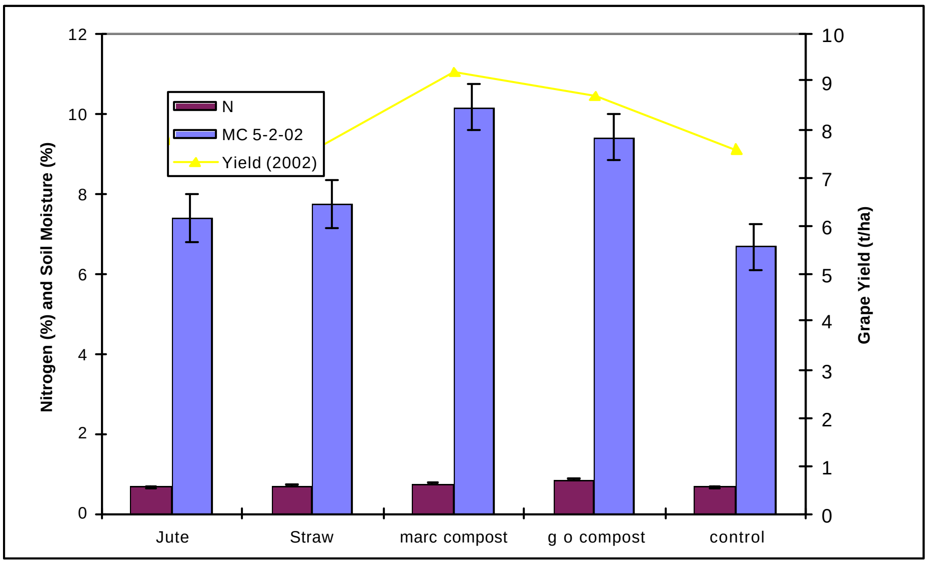


Figure 10: Langhorne Creek 2002, showing the relationship (r^2 =0.73) between yield (LSD=1.28), soil nitrogen content (LSD = .079) and moisture (LSD = 1.274)

This outcome is of considerable importance when discussing sustainable resource management. The application of recycled organic matter to the soil as compost in itself is an eco-friendly venture. In doing so, a yield increase of 51% was achieved at the Langhorne Creek site, simply by providing the vine with better soil nutrients and water status and thereby improving the water use efficiency. The use of recycled and composted organic matter on vines in this region is therefore recommended to improve yields and economic returns.

The application of compost was not always nutritionally beneficial to the vine. At the Banrock Station site, the vines are fertigated, and much larger quantities of water are applied over the growing season. It is possible that the mulches mineralised nitrogen in the soil, but this was rapidly removed, either into the vine or lost through volatalisation and leaching. Increases in petiole concentrations of soil minerals occurred with calcium, potassium and phosphorus, and declined with magnesium. These relatively stable soil minerals are less prone to leaching and represent valuable nutrient input from the compost products.

At the Clare site, significant differences in petiole nitrogen, manganese, zinc, potassium and phosphorus occurred to varying degrees through the use of the mulching materials. Of interest was the increase in petiole N from the straw mulch treatment, which is again explained by improved moisture relations leading to increased organic matter mineralisation rates. At this site, petiole nutrient levels were quite adequate for all elements tested for which there are published standards, so they were not a yield constraint. The exemption to this may have been molybdenum. Williams (2003) has found that inadequate levels of this element may be a cause of the 'hen and chicken' phenomena, which was evident in the Merlot variety grown at this site. However the minimum detection limits for molybdenum using the ICP system are below the adequate levels required for vines, so this could not be assessed.

Mulching at the Barossa site led to increases in petiole potassium using jute, forest mulch and compost but not by straw. Magnesium and phosphorus appear to be inversely proportional to one another – that is, increased petiole phosphorus leads to reduced magnesium. This outcome was also shown at Banrock Station (Appendix 5.6). Again, all nutrient levels were found to be in the adequate range.

6.1.6 Conclusion

Mulches may have a greater influence on vineyard productivity than just weed control. However, where weed control and moisture conservation are the primary objectives, cereal straw and grape stalks are the cheapest and therefore most cost-effective raw material to use. The compost products in some environments will provide nutrient benefits to the vine which can have significant effects on yield and to a lesser degree quality.
The outcomes of this work emphasises the need for trials to be conducted on site by the growers rather than relying on research results generated at other sites where management and environment may be quite different. Nutritionally, the compost mulches benefited the vines at Langhorne Creek and to a lesser degree at Clare, but were of no apparent benefit at the Barossa or Banrock sites.

6.2. Vineyard mid-row

6.2.1 Weed Control

Trials were established as four sites, with the cover crop species selected on a site specific basis. This section will therefore focus on these sites and discuss the individual treatments used and their efficacy. Pertinent to all sites is the variable rainfall experienced over the two years (2001/02) which resulted in tremendous differences in biomass production.

Clare

This high rainfall site with acidic soil (pH in H_2O – 5.4) characteristics was sown to the green manure and pasture species mixes shown in appendix 5. The biomass production in 2001 was very high on the green manure plots in particular, where the in-determinant growth habit of the legumes enabled utilisation of the additional moisture. The dominant weed species at Clare were capeweed (*Arctotheca calendula*), wireweed (*Polygonum aviculare*) and brome grass (*Bromus diandrus*). All the sown cover crops competed effectively with these species and produced a much greater amount of total plant biomass than the unseeded control. In these soils with low organic matter contents, high clay content and high rainfall, it is desirable to increase the soil organic matter content through mulching vigorous cover crops and leaving them on the surface. It would be expected that the three ryegrass / pasture legume mixes would be preferred in this role as they should all regenerate in the following years if managed to maximise the seed set in the first year. The establishment costs could therefore be amortised over many years, and soil organic levels would benefit considerably, as has been shown in long-term trials in South Australian broadacre systems.

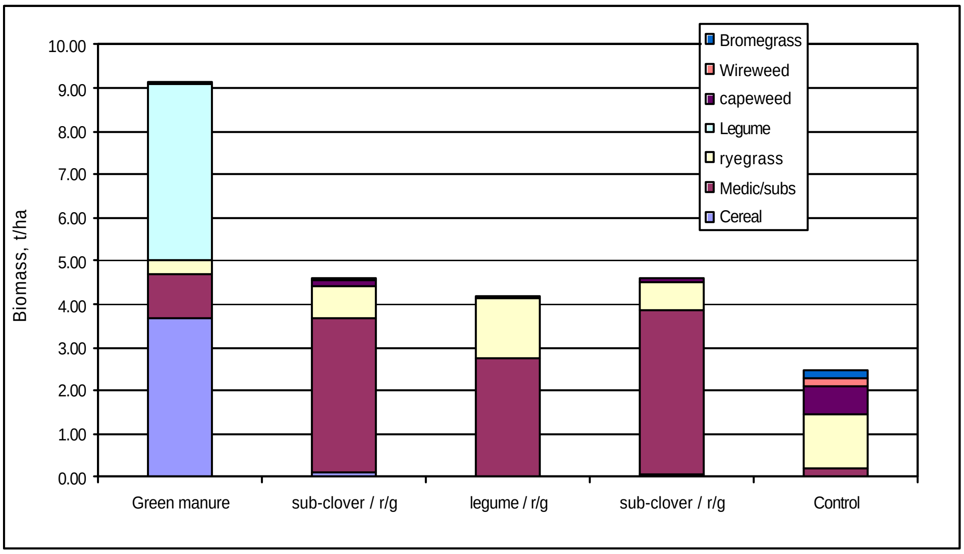


Figure 11. *Clare cover crop biomass production, 2001*

Banrock Station

The 2001 season at Banrock Station produced very good cover crop stands, but the 2002 season was a reality check, as there was no regeneration of the medic pastures, and the sown cereal green manure died soon after emergence. Results from the 2001 season are shown below.

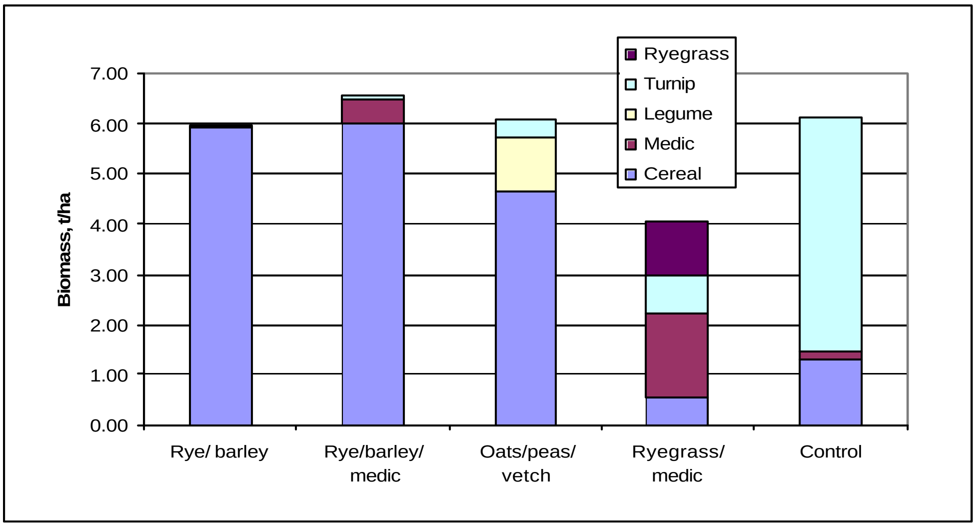


Figure 12: Cover crop biomass, Banrock Station, 2001.

The dominant weed at Banrock Station is long fruited turnip (*Brassica tournefortii*), as displayed in the nil treatment control. All of the cover crops competed strongly against the turnip, with the cereal mix of rye and barley performing the best of all treatments.

This outcome brings into question the definition of a weed. Turnip grows very well in this environment, and has established a substantial weed seed bank. It would seem to have no negative attributes if managed during the spring by mulching through rolling or slashing onto the ground surface. This prevents the dry plants breaking at the stem base and blowing against fences and vine rows. It has also been suggested that long fruited turnip has bio-fumigation properties in common with many brassica plants, and may thereby constrain the populations of harmful soil borne nematodes.

Would it therefore be more cost-effective in this environment to allow the endemic species to regenerate annually rather than growing annual cover crops as is presently the case? Rainfall in this environment is generally low, inhibiting biomass production from any cover crop. Drip irrigation systems are well recognised for their enhanced irrigation efficiencies compared to microjet and overhead sprinkler systems, so their use is to be supported in the Riverland / Sunraysia growing environments. Without sprinkler or flood irrigation, the growth of conventional cover crops using exotic species is going to be difficult and success will be rare. In addition, without moisture being applied to the mid-row, there will not be any vine root activity in that area, so there will not be any nutrient benefit derived by the vine from the cover crop.

Sowing annual cover crops requires soil disturbance, which even with direct drilling can be enough to encourage wind or water erosion. Management must therefore be directed in this environment to providing soil cover which does not involve sowing. It is therefore recommended that management of the endemic or naturalised volunteer species is a much better option than sowing cover crops in the Riverland region.

As reported by Thompson (2002), this approach has benefits for predatory control of light brown apple moth, which has associated savings in insecticide application along with the savings made from not sowing cover crops. This cost, estimated at approximately $85/ha in the Riverland / Sunraysia areas is significant, and does not include the negative environmental impact of soil disturbance in these fragile environments.

Barossa

The Barossa vineyard, which is managed by organic principles, had a very low weed population in the mid-row. It should be noted however that annual ryegrass has not been classified as a weed, as it is recognised by the vineyard owner as a valuable part of the species mix. The cover crops produced very large amount of biomass in the 2001 growing season as shown below, and competed very strongly with the dominant weed species (capeweed).

The sub-clover and medic mixtures of cover crop species performed very well, producing over 10 tonnes/ ha total biomass, including some 150 kg of biologically fixed nitrogen. This material could then be side thrown under the vines as a nutrient source, and managed to allow seed set in the mid-row every three or four years, thereby ensuring the regeneration of these cover crops over the long term. The only drawback of the leguminous pasture legumes as cover crops in this region is the possible hosting of light – brown apple moths, which may require manipulation of the species mix to provide habitat for predatory insects.

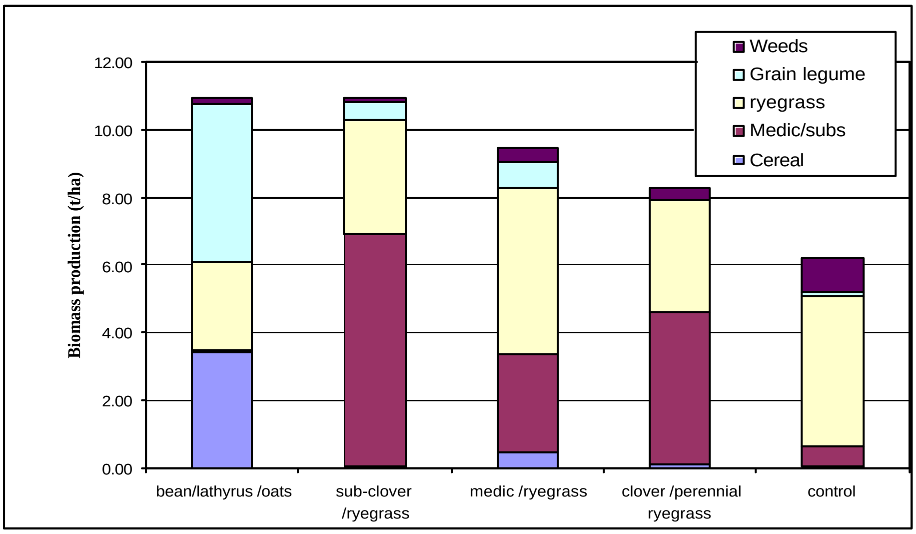


Figure 13: Biomass production, Barossa, 2001

Langhorne Creek

The Langhorne Creek site was the last sown in 2001 and is in a lower rainfall region than Clare and the Barossa, which accounts for the lower levels of biomass production. Cereal rye is well suited to this environment, and in combination with barley is a very competitive mix.

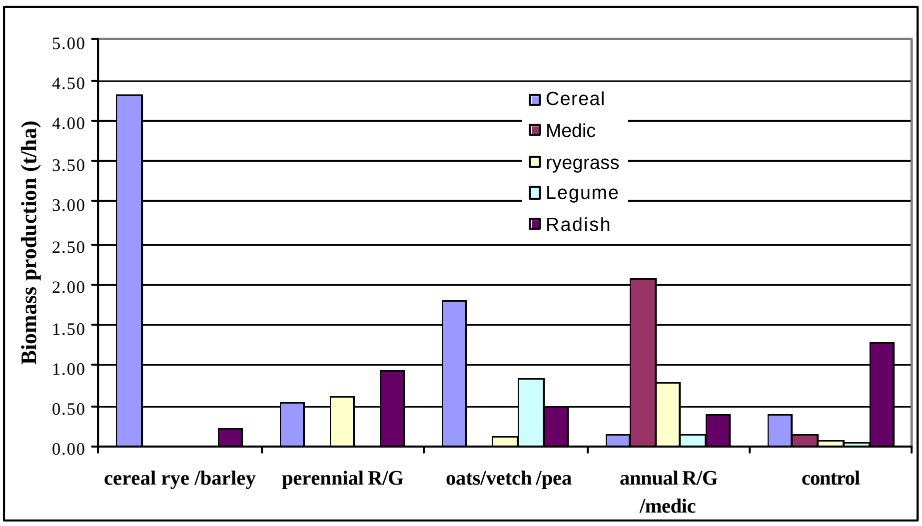


Figure 14: Biomass production, Langhorne Creek, 2001

Radish (*Raphanus raphanistrum)* in itself is a strong competitor and was the dominant weed at this site, but its growth was subdued very effectively by the cereals. Broadleaf crops and pastures by comparison did not restrict radish growth as effectively. Perennial ryegrass is the main cover crop on this property, but as shown it does not compete well with radish. Its suitability to the environment however would suggest it should continue to be used as a cover crop, and the radish managed using the sponge wiper developed in this project, which would provide selective control based on plant height and minimise control costs by using low rates of non-selective herbicide.

Conclusion

The capacity for mid-row cover crops to contain the growth of weeds in a range of environments has been displayed in this component of the trial. Cereal crops, and in particular cereal rye, barley and triticale, are very strong competitors given suitable conditions for growth. However, even these crops need to be weed free in their early stages of growth. Therefore, weeds such as soursob (*Oxalis spp.)* are going to be very hard to control by cultural means alone. Using oxalis as an example, it is necessary to determine if the soursob is really a weed, and if not, they can be left in situ to compete with other less desirable plants and provide very cheap and colourful ground cover over the winter and spring periods.

As noted earlier, the justification for growing a cover crop needs to be established prior to species selection. Once the need is recognized, suitable species can be selected to fulfil the required tasks in most situations, and with good agronomic practice the required outcome can be achieved.

6.2.2 The impact of cover crops on vine nutrition

Introduction.

The role of the mid-row area in the total vineyard context needs to be well defined, as it accounts for some two thirds of the floor area on land which is often highly valued in financial terms. Does the cover crop earn its way in terms of providing the vine with nutrition, or is it instead a ground cover with other functions such as impeding weed growth, preventing erosion, improving soil properties to enhance water storage and root access and increasing the floral biodiversity of the vineyard and thereby beneficial insect habitat.

The literature provides scarce information to quantify the value of soil nutrition contained in the mid-row to the vines. The cover cropping sites established to investigate weed control were therefore also used to begin investigating this important question, because the role of the cover crop will have a direct influence on the species to be grown in the mid-row, which will ultimately affect weed management.

Results and discussion

In this short duration trial, there were no apparent differences between cover crop and the nitrogen status of the vine at the Clare, Barossa or Langhorne Creek sites. Banrock Station was not investigated because the irrigation practice used and the environment made root activity in the mid-row very unlikely. The Barossa site in 2001 produced in the vicinity of

150 kg of nitrogen per sown ha (treatment 2, figure 13), or about 90 kg of nitrogen per ha of vineyard floor, which includes the vine row. Of this amount, it is expected approximately 30% would be mineralised and available for the following crop. With vines in this block yielding approximately 9 t/ha, the replacement nitrogen requirement would be 9-15 kg/ha. If the vine roots were actively sourcing water and nutrients from the mid-row, the 50kg of mineralised and available N from the cover crop should have been observed as an increase in petiole N compared to the control, but this did not occur.. Despite the lower than average rainfall experienced in 2002, it would still be expected that roots which were active in the mid-row would have accessed nitrogen and water.

This anomaly may also be explained by the indifference of grapevines to nitrogen application. Freeman (1987) makes note of the frequency of poor response to N fertiliser found in nutrition experiments with grapevines. There may also be a lag period before the response is observed, as reported by Robinson (1987) for a nutrition trial in non-irrigated vines in the Barossa.

It is concluded that further work on this subject is required, because the mid-row accounts for such a large proportion of the vineyard floor, its management can be very costly, and its value to the vines is under question. Further work should therefore ascertain and provide guidelines for best practice floor management on a regional basis.

6.3 Cover crop Management – Roseworthy Trials

Introduction

There are many approaches used in the termination of cover crops. Frequently they are slashed then sprayed to kill regrowth. Other approaches are slashing followed by rotary hoeing and side throw slashing. To minimise frost damage, cover crops are seldom left standing, and rotary hoeing is often justified by growers to reduce frost risk. However, exposing the soil through cultivation and reducing cover crops to fine particle sizes by mulching, would appear to be encouraging summer weed problems. A trial was established at Roseworthy in 2001 to investigate the effect of different cover crop termination practices on wireweed (*Polygonum aviculare)* growth over the summer period.

Results and Discussion

2001.

While there were no differences in wireweed biomass or populations between termination treatments, there was between cover crops, as shown in figure 15 below.

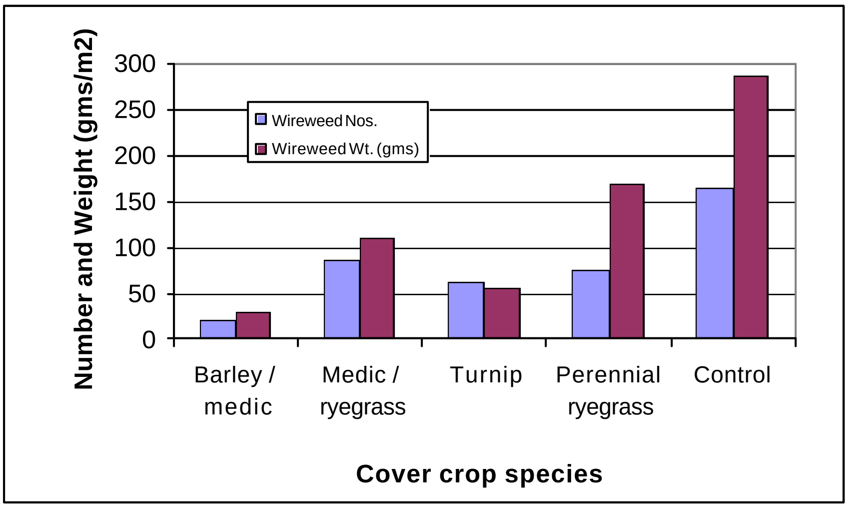


Figure 15: The influence of cover crop species on the germination and growth of wireweed, 15-3-02. (LSD numbers = 14.8; weights = 23)

The barley (var. Mundah) appeared to display a strong negative allelopathic influence on the wireweed. This outcome would suggest that the choice rather than the treatment of cover crop might be the most important criteria in the reduction of wireweed populations over summer.

2002

The methods of terminating cover crops (see plate 1) had a dramatic impact on summer weed populations. The trend shown below (fig. 16) is for the greater the area of bare soil, the greater the weed population. There was no difference between mulching and rolling the cover crop. Rotary hoeing is significantly different to rolling and mulching, where an ideal soil medium is created for weed germination without the smothering effect of mulches laid on the surface. These mulches may also lead to

Plate 1: An investigation of cultural practices in summer weed control, where barley has been mulched (left of picture), rolled (centre) and mulched followed by rotary hoeing (right of picture).

insect predation of weed seeds, as the mulched soil creates habitat for creatures such as ants.

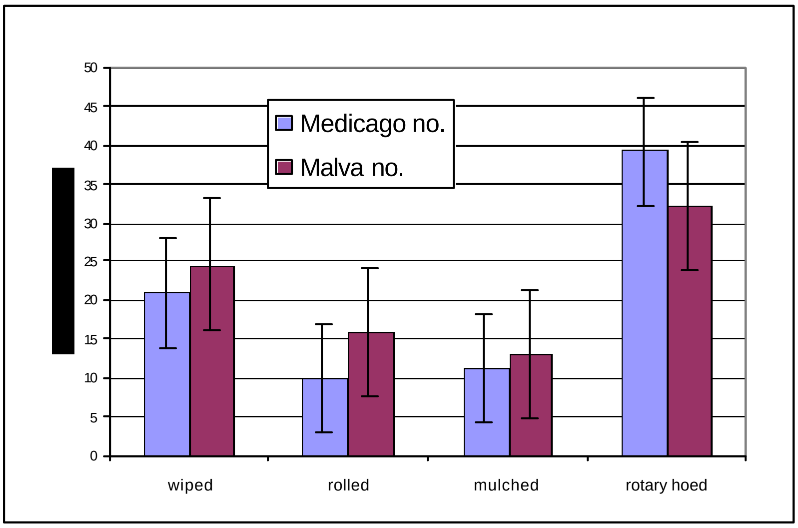


Figure 16: The effect of cover crop termination treatment on weed germination.

It has been established in this trial that cover crop selection is an important determinant of weed suppression during the growing season. This small short-term trial suggests that the selection of cover crop and the treatment of that cover crop is also likely to influence summer weed populations. These are important outcomes, as it is the summer weeds which have the greatest influence on soil moisture availability to the crop, and are the hardest and most expensive to control due to canopy development restricting the herbicides available for use. This work has just begun to explore the potential for cultural techniques of weed management in vineyards, but it has shown that through some simple, cheap alterations to management it may be possible to significantly reduce herbicide requirements for summer weed control.

6.4 Machinery Development

Introduction

The potential for adaptation of machinery to suit vineyard applications, that would lead to reduced herbicide application and / or soil tillage, was investigated in this project. The following machines were developed, tested and made available to producers for demonstration during the project:

1. Ribbed roller

This was developed as a cheap, low maintenance means of cover crop termination that would maintain the integrity of the cover crop on the soil surface, thereby improving its

mulching effect and reducing the rate of breakdown. The roller (plate 2) served these functions very well in most circumstances. It worked superbly in tall cereal, brassica or weedy cover crops on either flat hard ground or soft soil. If the ground was hard and uneven, the cutting or creasing mechanism of the ribs against the soil surface was not possible where a gap existed under the ribs of the roller. Where the soil was soft and uneven this was not an issue, as the blades were able to compensate in cutting depth.
This machine generated a considerable amount of interest when displayed at the Watervale and Riverland field days, with several farmers saying they were going to build them at home.

Plate 2: A ribbed roller developed for termination of cover crops.

2. Sponge wiper
Selective weed control in vineyards is often necessary to remove undesirable species from a stand of preferred species, or all plants from within an actively growing canopy. The herbicides used to achieve selective control are often expensive, or where non-selectives are used, there is the potential for herbicide drift onto the vine.
Sponge wipers are a derivation on wick wipers which have been available for many years. Concentrated glyphosate herbicide with a dilution of 1:3 or 1:5 is applied to plants that contact the wet sponge. Selectivity is gained by adjusting the operating height, making it possible to remove tall growing species (eg Salvation Jane) from a cover crop (eg. Ryegrass). This is achieved using the cheaper, low mammalian toxicity broad-spectrum herbicide without any fear of herbicide drift onto the vines as there is no atomisation of the chemical mixture involved.
A derivation of the sponge wiper for use in the under-vine area was also developed with additional funding ($3,000) provided by GWRDC (plate 3). This machine provided the benefits of sponge wiping while retracting around vine trunks and posts.
The sponge wipers attracted a considerable amount of attention at the field days, as growers realized their potential in preventing herbicide drift while effectively removing unwanted weeds.

Plate 3: A sponge wiper for weed removal in the mid-row and the undervine area, mounted on an ATV bike.

3. Bezzerides under-vine weeder.

This machine (see plate 4) was donated to the project by the Bezzerides company in California. It was included in the project to potentially provide a low cost option for mechanical under-vine weed control. It was loaned to four growers for evaluation during the coarse of the project. Where soil conditions are suitable and the vineyard is configured to handle the machine (set row widths, no exposed irrigation risers, established vines with trunk diameters of 30 mm minimum) the machine worked very well, leaving weeds to desiccate on the soil surface. The lack of an agent in Australia and caution on the producers behalf that it can reliably work given its simplicity has to date hindered the purchase of any machines.

Plate 4: The Bezzerides under-vine weeder being evaluated in a Langhorne Creek vineyard.

6.5 The preliminary investigation of perennial native species as suitable vineyard cover crops.

Introduction

The cover crops currently used in Australian vineyards are either exotic species usually grown as broadacre crop or pasture plants, or resident regenerating weed species. The potential for the use of native perennial plant species is considerable, as they are well adapted to the Australian environment, and may provide additional biodiversity to the vineyards.

A preliminary assessment of a range of cover crops, based on their ability to compete with weeds and their soil water use, was therefore undertaken in a paddock situation without vines at Roseworthy Campus. The species chosen for this trial are listed in table 4.

The trial was established in the August / September period of 2002. The ryegrass was sown as seed, while all other plants were hand sown as seedlings following purchase from a local nursery. To guarantee establishment, the plots were irrigated with soaker hose until 9/11/02 then became rainfed as a test of their survival over summer. Soil moisture was determined monthly using a neutron probe. The area surrounding the access tube over a 1.5 metre diameter zone was maintained weed free, and the control was bare soil. Weed biomass measurements were obtained using a 1000 cm^2 quadrat from 2 sampling sites per plot (beyond the weed free zone), which were sorted in primary weed species, dried and weighed.

Plate 5: Chloris truncata (windmill grass) surrounding an aluminium neutron probe access tube, native perennials trial site, Roseworthy, 2002.

Soil Water Use

Three species viz Myoporum, Phyla and Dichondra performed poorly in this environment without additional irrigation, while the others established and continued to grow well over the summer period.

Figure 17 below shows the significant changes in soil water content from 70 – 120 cms depth for the last reading prior to the opening rains in 2003. The trend over the $4^1/_2$ month period of moisture measurements, was for the perennial ryegrass to show the driest profile until it senesced, in December.

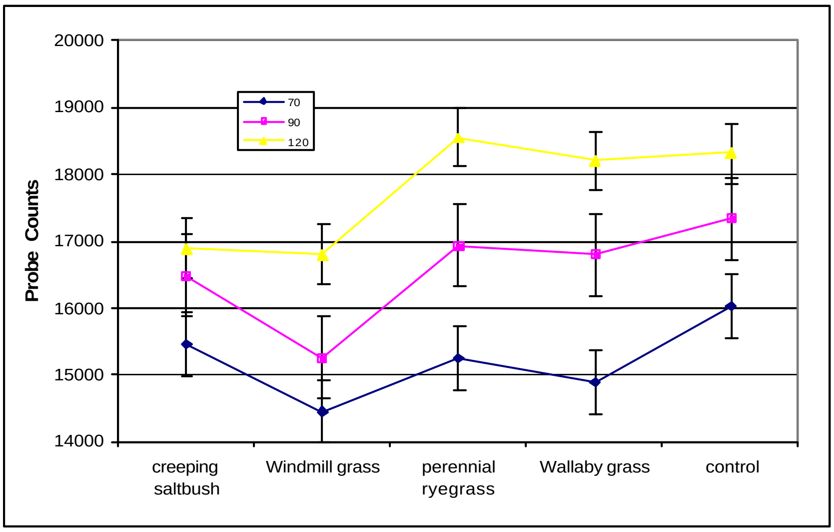


Figure 17: Neutron probe counts to determine soil moisture at three depths, native perennial plants trial, Roseworthy, 9-4-02

For the 2003/04 season, readings are continuing to be taken, despite the trial now being unfunded. This is important because the treatments now comprise mature plants, so the results have greater relevance than those from the first year of the trial. Wheat straw mulch has replaced the Myoporum spp as a second control. Table 6 below shows the significant differences in soil moisture at three depths, and these results extend to 90 cms. At all depths, the wallaby grass and windmill grass use more water than the bare earth control, while the straw is very effectively reducing evaporative losses. The soil profile contained less water under creeping saltbush only at 70 cms. but appears to be conserving water in the shallower profile. Creeping saltbush forms a very dense prostrate matt of foliage which reduces evaporative losses. It is expected this plant will therefore have a similar moisture profile to the bare soil control until the surface horizons dry, causing the roots to extract from deeper in the profile.

The Wallaby grass is a winter active C3 plant while windmill grass is a summer active C4 species. Both species appear to be using similar amounts of water to perennial ryegrass, which is now commonly grown in vineyards. Unfortunately, straw is not an option for covering the mid-row due to its cost. If it is recognised that it is desirable to have coverage of the soil on the vineyard floor, can natives provide a desirable option to conventional cover crops? This is very likely, because they are well suited to the environment, require minimal maintenance and are perennials. Where the native species compliment the ecology of the vineyard they may be desirable to establish. Are they cost effective? At present the establishment of natives in the vineyards is expensive, but it is expected that with the development of seed orchards to provide cheaper seed, and the development of improved seeding systems, costs can be reduced considerably, and such species can viably be introduced to the vineyard ecosystem.

Table 6: Neutron probe counts used to determine soil moisture at six depths, native perennials trial, Roseworthy, 30-10-03. Those measurements which are significantly different ($P < 0.05$) to the control are shaded.

Depth	**Creeping saltbush**	**Windmill grass**	**straw**	**perennial ryegrass**	**Wallaby grass**	**control**	**F calc**	**LSD**
15	9435	7378	14806	5138	6695	9222	0.002	3502
30	16636	16509	22578	16290	15173	18612	0.003	2992
50	16953	16317	22500	15168	14942	19831	0.001	2854
70	17399	16394	21643	15546	15324	19616	0.001	1985
90	17276	15644	20161	16856	16179	18064	0.001	1622
120	17116	16824	17635	17947	18347	17687	0.15	1204

Competition with weeds

Results and Discussion

Visual observation of the site suggested there were considerable differences in the competitive capacity of the sown species with weeds. However, the site variability overweighed the treatment effects at the time of sampling. Sampling will again be undertaken in 2003/04 to determine the impacts of a mature stand on weed populations.

7. OUTCOMES / CONCLUSION

This project has produced several worthy outcomes, which are listed below.

1. Mulches applied under the vine rows will impact on weed populations. Wheat straw was the most effective inhibitor of weeds. Compost based mulches inhibited the growth of most weeds, but if seed rain from the mid-row occurred, they also presented a very desirable growing medium for weeds. Grape stalks and stems were equally useful at reducing weed growth as the composted products. Jute matting was very effective in its first year after application, but was also prone to supporting weed growth after seed shed. It also began decomposing during the second year, which further reduced its efficacy.

2 Mulches can provide additional nutrient and water conserving benefits in some environments, resulting in yield increases up to 50%. Their benefit to the vine will depend on the soil nutrient status, soil type, irrigation application rate, grape yields, and fertigation practices
3 The role of the mid-row area in a vineyard needs to be defined. This will vary according to rainfall, irrigation system, soil type, wheel track compaction, vineyard age, rootstock and establishment techniques and management preferences.
4 Where the mid-row has little impact on vine growth and production, management can be directed to minimising cost. If instead it is a source of nutrients for the vines, then suitable cover crop species can be grown, then side thrown under the vine in spring. If it is a source of water, then low water use crops should be grown and a weed free mulch maintained on the soil surface to prevent evaporation.
5 The growth of competitive cover crop species using good agronomic practice can effectively suppress the growth of most winter weed species.
6 Barley (var. Mundah) appears to have strong allelopathic effects on wireweed, an important summer weed of vineyards.
7 Practices used to terminate cover crops can impact on summer weeds in the mid-row. Tillage encourages weed germination, while leaving the cover crop as a mulch on the soil surface, either by rolling or slashing, discourages weed germination and growth.
8 Sponge wipers could play a valuable role in vineyard weed control while minimising herbicide application. An attractive feature of this form of herbicide application is they generate no fine particles, so drift is not an issue, enabling the use of glyphosate when the canopy is developed.
9 Native perennials provide an attractive option to conventional cover crops as weed suppressants.

This project has been valuable in consolidating other related work such as that conducted by Porter on cover crops and and Buckerfield and Websters work on mulches. It has extended that work into a systems based approach to floor management, where the impact of practices designed to reduce weed growth has been quantified in terms of impacts on grapevine yield and must quality. An extension to this applied research has been the development and testing of a ribbed roller for cover crop termination, and a sponge wiper for mid-row and undervine weed control and the use of native perennial plants as potential options for cover crops. The project has determined the potential for numerous products and technologies to cost effectively reduce the need for herbicides in vineyards. Grower verification through on-farm trials to test the validity of these research outcomes over a range of environments is now required and should lead to the adoption of many practices, which ultimately will reduce herbicide usage in Australian viticulture.

8. RECOMMENDATIONS

1 The outcomes of this work need to be transferred to the grower community. This may occur through articles written by the principal investigator, but also requires an active extension process to disseminate the information.

2 The role of the mid–row in vineyards of the many regions of Australian viticulture needs to be defined. If it is found to provide significant benefit to the vines, then it should be managed accordingly, with cover crops selected, grown and managed to serve the requirements of the vine. Where the mid-row has no impact on vine performance, management should be directed to minimising cost and maximising soil conservation protocols.

3 The benefits achieved through mulching would suggest considerable increases in irrigation efficiency can be achieved through closer attention being paid in some regions to soil improvement. The common practice of removing all vegetation from the under-vine area by herbicides or cultivation leaves a bare soil with declining organic matter levels and subsequent reduction in soil health. This will ultimately lead to reduced yields and potentially poorer quality fruit, as the terroir of the vineyard deteriorates through poor soil health. A research program to address this issue is therefore necessary.

4 Native perennial ground covers and grasses may have considerable potential as mid-row cover crops. They seem well adapted to a wide range of environments, and their water use and weed competitiveness suggests they could be well suited to vineyards. However, their establishment is presently expensive. The development of seed treatment techniques for a range of native species, that will enable ready establishment through conventional seeding equipment will make the adoption of native perennials in Australian vineyards more readily accomplished.

APPENDIX 1: COMMUNICATION

Conference Papers

Penfold, C.M. (2002) Weed management for organic viticulturalists 7th International Congress on Organic Viticulture and Wine, Victoria, Canada

Penfold, C.M. (2002) Weed Management in Organic Viticulture, Biological Farmers of Australia Conference, October 3-4, Lismore, N.S.W.

Penfold, C.M. (2002) Weed management without herbicides in *Environment SA* Vol 9, No. 2, 2002.

Penfold, C.M. (2002) Herbicide reduction strategies for winegrape production In: 2nd National Wine Industry Environment Conference and Exhibition, November, 25-26, Adelaide, S.A.

Workshops

Weed Management in Organic Viticulture, Australian Wine Industry Technical Conference, September 11, 2001, Adelaide.

Soil and Weed Management in Organic Viticulture. Organic Viticulture Workshops, Loxton and Mildura, September 2002. Convened by C.M Penfold and D. Madge

Cover Cropping, WineTech, Adelaide, July 16-17, 2003

Industry Journals

Australian red and whites go green in LAB News, February / March, 2001.
Weed control study encouraged by Sharon Watt, National Grapegrower magazine, December 2001.
Options trialled for weed control by Sharon Watt, National Grapegrower magazine, December 2001.
New project with a focus on reducing herbicide use by Kate Dowler, National Grapegrower magazine, June 2002
Cover cropping – an agronomists perspective in Grapegrower and Winemaker, No. 473, June 2003.
Weed Management in CRCV Newsletter, January – February, 2003
Native grasses a better option in National Grapegrowers, July 2003.
Cover crops and vine nutrition in Grapegrower and Winemaker, No. 478, November 2003
Weed suppression with mulches, Viticare News, November, 2003

Field Days

Watervale Field Day, Clare Valley, 2002 and 2003.
Riverland Field Day, Barmera, 2002.

APPENDIX 2: INTELLECTUAL PROPERTY

No intellectual property rights have arisen from this project. Patenting the undervine sponge wiper has been talked about but has not been pursued.

APPENDIX 3: REFERENCES

Agnew, R.H., Mundy, D.C. and Spiers, M. (2003) Effects of organic mulch on soil and plant nutrients in The Australian and New Grapegrower and Winemaker, Annual Technical Issue No 473a pp 33-38

Buckerfield, J. and Webster, K (2001) Responses to mulch continue – results from five years of field trials. The Australian Grapegrower and Winemaker No. 453.

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Ingels, C.A., Bugg, R.L., McGourty, G.T, Peter Christensen, L. (Edrs.)

Hunt, N. and Gilkes, R. (1992) Farm Monitoring Handbook. University of Western Australia Press.

Kalburtji-KL; Mosjidis-JA; Mamolos-AP (2001) Allelopathic Plants *in* Allelopathy-Journal. 2001, 8: 1, 41-50

Freeman, B. (1987) Grapevine requirements for nitrogen *In* Vine Nutrition. Proceedings of a seminar organised by the Ausralian Society for Viticulture and Oenology, AWRI, South Australia. Lee, T.H. and Freeman, B.M. (Edrs)

Porter, R. (1999) The role of inter-row ground covers to improve the management and sustainability of soils in Australian vineyards. Vol 1 & 2, GWRDC project no. 93/1

Thompson, R., National Grapegrower, May 2002

Wilkinson, K and Biala, J. (2001) Managing soil nutrients with compost. The Australian Grapegrower and Winemaker No. 454

Wilkinson, K. (2003) Getting the most out of composts and mulches. Australian Grapegrower and Winemaker No. 478

Williams, C. (2003) Molybdenum may improve fruit set *In* Australian Viticulture, Vol. 7, No. 2, March-April., pp 31-34.

APPENDIX 4: STAFF

Chris Penfold and casual staff as required.

APPENDIX 5:

Appendix 5.1 Cover crop species, as sown in 2001.

Green manure	Icarus beans
	Lathyrus cicera
	Marloo oats
Regenerating	Wimmera ryegrass
sward	Antus subclover
	Caliph burr medic
	Dalkieth sub clover
Regenerating	Wimmera ryegrass
sward	Prima
	Fronteir
	Mogul
Perennial	Permagreen 1
	Losa sub clover
	SA 5045
Control	no planting

Clare cover crop treatments

Green manure	Icarus faba bean
	Lathyrus cicera
	Marloo Oats
Regenerating	Wimmera ryegrass
sward	Prima gland clover
	Sava snail medic
Regenerating	Wimmera ryegrass
sward	Fronteir balansa
	SA5045
Perennial	Permagreen 1
	Sapo
Control	Volunteer plants

Barossa cover crop species

Cereals	Bevy rye plus
	Mundah barley
Regenerating	Bevy rye plus
sward	Mundah barley plus
	Caliph medic
	Harbinger AR
Green manure	oats /peas /vetch
Regenerating	Wimmera rye plus
sward	Caliph medic
	Harbinger AR
Control	volunteer plants

Banrock cover crop species

Cereals	rye
	barley
Green manure	oats
	peas
	vetch
Regenerating sward	medic
	ryegrass
Perennial sward	ryegrass
Control	volunteer plants

Langhorne Creek cover crop species

Appendix 5.2. Chemical analysis of grape marc compost, green organic compost (nitra mulch and Jeffries compost) and forest mulch products prior to application.
(Note: pH, EC, Salinity, TDS analysed at Roseworthy Campus Soil Laboratory)

	N	**Fe**	**Mn**	**B**	**Cu**	**Mo**	**Co**	**Ni**	**Zn**	**Ca**	**Mg**
	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
GRAPE MARC COMPOST L/H CK	2.3	3700	137	51	99	1.8	1.7	5.5	132	13600	3000
GRAPE MARC COMPOST BANROCK	2.5	2900	151	44	72	1.7	1.4	5.4	148	17900	3500
NITRA-MULCH BANROCK	2.2	11300	260	32	68	1.7	4.1	15	290	29000	6000
NITRA-MULCH L/H CREEK	1.4	13300	250	60	99	1.5	5.7	14	440	39000	6500
JEFFRIES COMPOST	1.2	10200	230	43	70	1.6	3.9	13	310	32000	5000
FOREST MULCH	1.1	5900	102	33	31	2.5	2.2	16	130	20000	3200

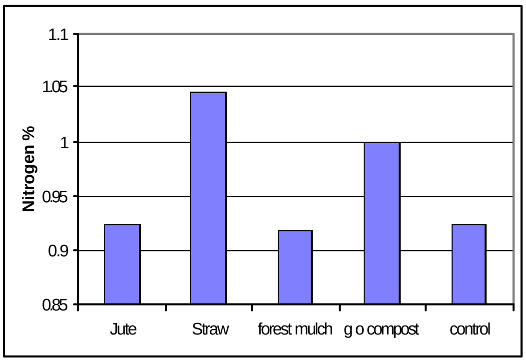
	Na	**K**	**P**	**S**	**Al**	**Cd**	**pH**	**pH**	**EC**	**Salinity**	**TDS**
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	H20	CaCl	mS	%	mg/L
GRAPE MARC COMPOST L/H CK	1360	34000	5000	3000	3400	< 0.6	7.5	6.8	6.2	3.3	3260
GRAPE MARC COMPOST BANROCK	1760	27000	5400	2900	3100	< 0.6	7.1	6.6	5.8	3.2	3130
NITRA-MULCH BANROCK	2400	13100	4100	6800	11600	< 0.6	6.8	6.5	5.2	2.8	2740
NITRA-MULCH L/H CREEK	2500	14800	3100	3700	13200	1.1	8.2	7.5	4.0	2.1	2040

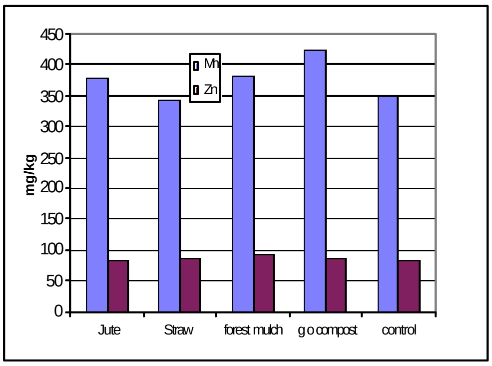
JEFFRIES COMPOST	1880	10900	2400	2600	9500	0.77	7.9	7.2	3.5	1.8	1800
FOREST MULCH	1760	8500	1230	1800	5200	< 0.6	7.0	6.5	3.5	1.8	1750

Appendix 5.3 Grape quality as influenced by mulching treatment, Langhorne Creek and Banrock Station sites, 2003.

	Baume	**pH**	**TA**	**phenolics**
Treatment	**Langhorne Creek**			
jute	13.84	3.68	5.44	10.9
straw	13.38	3.58	6.24	9.89
grape marc	13.46	3.78	5.68	9.76
compost	13.5	3.42	6.36	10.24
control	13.8	3.75	5.44	10.99
Treatment	**Banrock Station**			
jute		3.57		
straw		3.58		
grape marc		3.68		
compost		3.59		
grape stalks		3.63		
control		3.6		

Appendix 5.4: Petiole analysis results, Clare 2002, for (a) nitrogen (LSD = 0.0741), (b) manganese (LSD = 55) and zinc (LSD = 8.6) and (c) potassium (LSD = 5733) and phosphorus (LSD = 975).

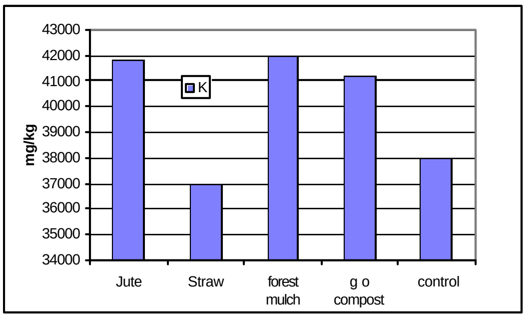


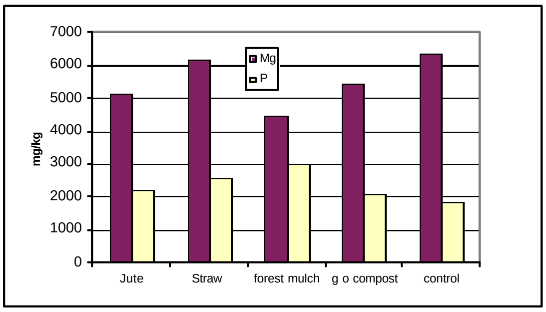


(a) (b)

(c)

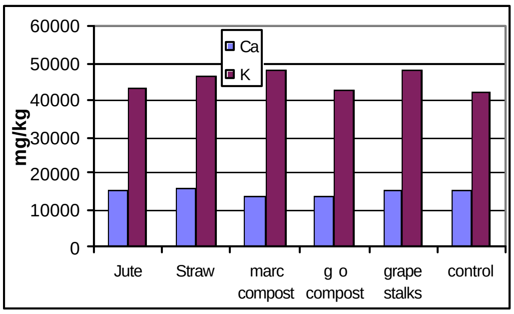
Appendix 5.5: Petiole analysis results, Barossa 2002, for (a) potassium (LSD 0.05 = 3422),(b) magnesium (LSD = 757) and phosphorus (LSD = 706)

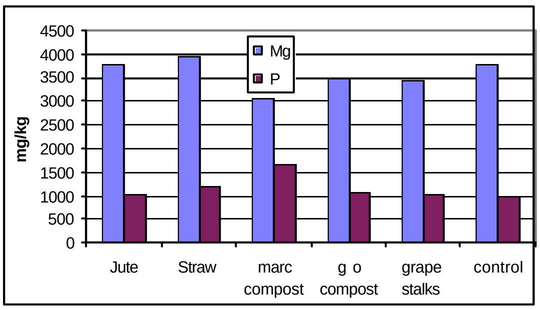




(a) (b)

Appendix 5.6: Petiole analysis results, Banrock 2002 for (a) calcium (LSD = 574) and potassium (LSD = 2710) and (b) magnesium (LSD = 273) and phosphorus (158)





(a) (b)

APPENDIX 6. ACKNOWLEDGEMENTS

The funding of this project by the Grape and Wine Research and Development Corporation, and the support of the program leader, Dr. DeeAnn Glenn, is gratefully acknowledged. The support of the vineyard managers at Southcorp Clare (John Matz), Banrock Station (Ben Vagnerelli), Rosemount Langhorne Creek (Darren Aworth) and Ann Wells, and in-kind

support from Seedco, Jeffries Garden Supplies, Peats Soils, Vineyard Straw Spreading, Bezzerides Bros. (California), Michael Richards and SARDI has been tremendous, and enabled the successful completion of the project.

APPENDIX 7: BUDGET RECONCILLIATION

See attached Form B – Statement of Receipts and Expenditure