Recycled Organics Unit

Recycled Organics Products in Intensive Agriculture

Volume 2 – Viticulture

A review of recycled organics products application field trials in viticulture in Australia

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Executive Summary

Background

The potential benefits of recycled organics (RO) products in viticulture have been studied in Australia over the last five years using a range of composted products. However, most of this research has not been peer reviewed or published, and is not readily accessible. Therefore the objectives of this report were to review relevant project reports, publications, presentations and articles in viticulture to:

- Establish baseline performance data for the use of RO products for viticulture application within the context of environmental factors and farm management systems;
- Review the methodology of previous trials, document key experimental design issues for applied field trials and to prioritise relevant monitoring parameters for the purpose of establishing the performance benefits and cost-benefit advantages of the application of RO products;
- Identify gaps in available data, thereby informing and prioritising future applied product application trials, and
- Inform the future development of performance-based RO product standards and application guidelines for the viticulture market segment.

Opportunities for inclusion of RO products into viticulture

Grapes are grown throughout the NSW state. The total area occupied by viticulture in NSW was 34,559 hectares (ABS, 2001). The main viticulture regions in NSW outside the Sydney Metropolitan region and within 300-400 km radius of Sydney are the Hunter Valley and Central West. The Hunter Valley currently occupies about 4,016 hectares under grape cultivation (ABS, 2001). The Central-West region occupies about 3,815 hectares (ABS, 2001). The total area under viticulture in the central-west has increased significantly since the last census in 1997 when it was about 779 hectares (only fruit bearing) (ABS, 1997). About 344 hectares are occupied in Yass and Young on the NSW South Coast. Smaller holdings exists in the Sydney metropolitan area occupying about 272 hectares and Macarthur and Illawarra regions occupying about 155 hectares mainly in Kiama, Shoalhaven and Wingeecarribee areas (ABS, 2001).

As discussed in Volume 1, Section 3.2 (ROU, 2003), intensive working of land used under intensive agriculture production systems is prone to loss of soil organic matter (SOM). This loss results into soil structure decline, land degradation and loss of soil productivity. Similar consequences apply to viticulture production systems. Recycled organics products when applied to the soil surface as mulches reduce growth of weeds, evaporation of water from the soil surface and retains soil moisture. Recycled organics products also contain organic matter and nutrients, and when applied to the surface of the soil (surface mulch) or incorporated into soil (soil conditioners) organic matter decomposes slowly over time and integrates with the mineral component of the soil improving soil conditions. Consequently soil productivity and crop production is maintained and land degradation is prevented. The nutrients present in RO products are released steadily over time and become available for the growth of grapevine. The use of RO products in viticulture therefore has opportunities to address the following agricultural and environmental issues:

- Weed suppression resulting in the reduction or avoidance of herbicides,
- Reduced evaporation of water from soil surface. Increased soil moisture may lead to reduced use of irrigation water for irrigated conditions and water conservation in non-irrigated conditions,
- Sustained and long term release of nutrients for growth of vine thereby reducing the use and manufacturing of chemical fertilisers,
- Reduced fluctuation of soil temperature resulting in reduced crop stress,
- Increasing soil organic matter leading to improved soil health and productivity, and prevention of land degradation, and
- Assist with conversion to organic production systems.

Conclusions

Field trials conducted across Australia using RO products have demonstrated a range of performance benefits to viticulture. The performance benefits of RO products used as surface mulches and soil conditioners in viticulture from the review of 27 field trials carried out across Australia have been summarised in Table 1 and the main performance benefits are discussed below.

Soil moisture

Application of RO products as a surface mulch increased soil moisture from 40 to 300%, and the mulching effect to increase soil moisture has been sustained over a long time (up to 4 years), although only one trial of this duration has been implemented. Addition of soil conditioner also increased soil moisture in the range of 50-60% (based on one trial and one off measurement only). Thick mulches (>10 cm deep) had greater effect to increase soil moisture. Increased soil moisture does not, however, relate directly to increased plant available water in the soil. It is the increase in soil moisture that is available for plant use, known as plant available water, that directly reduces plant stress and potentially reduces requirement for irrigation. An increase in soil moisture that reduces irrigation water requirements carries great importance for growers in rainfed as well as in irrigated conditions (under properly managed irrigation systems), but this relationship has not been evaluated in any of the scientific trials. Soil water is a limiting factor in agricultural production. Water deficit can result in increased plant stress, and significant reduction in yield or even crop failure. With implementation of the NSW Government's water reforms, growers are under increasing pressure to pay higher water prices based on volume of water extracted for irrigation. If mulch application demonstrates reduced water requirement in irrigated agriculture (under properly managed irrigation systems) and/or moisture conservation in dryland (rainfed) conditions, this can substantially reduce growers water bills and/or reduce risk of crop stress/failure, thereby providing significant incentive for incorporating RO products into farm management practices.

Table 1 Summary of performance benefits of RO products application to viticulture.

Performance categories	Performance outcomes	RO products as surface mulches	RO products as soil conditioners	Comments
Reduced risk to crop failure	Incidence of pest and diseases	Not investigated.	Not investigated	Specialised mulches e.g. containing phenolic compounds have the potential to suppress diseases.
	Frost risk in cooler climate	Composted mulches did not cause frost damage (3).	Did not cause frost damage (1).	Thick mulch application rates (>10 cm) and pasteurised mulches may increase frost risk.
	Crop stress in hot climate	Potential to reduce crop stress (1).	Not investigated	Crop stress can influence yield, vigour and incidence of pest/disease.
Increased revenue	Fruit yield	Mainly unaffected but lower rates have reported the potential to increase yield (~20).	Mainly unaffected but lower rates have reported the potential to increase yield (1).	Higher mulching depths (> 10 cm) & soil conditioners rates (15 lt/vine) are not effective and beyond that point may cause other negative effects.
	Fruit quality	Mainly unaffected (~17).	Not investigated.	Specialised mulches e.g. containing phenolic compounds have the potential to improve fruit and wine quality.
	Time to market	Not investigated	Not investigated	
Reduced farm management costs	Weed suppression	Confirmed weed suppression from 60-100%. Weed suppression decreases over time (~11).	Do not suppress weeds (~2).	Deeper mulches (15 cm) are more effective in weed suppression but beyond a point have the potential to cause other deleterious effects.
	Reduced irrigation water usage	Confirmed significant increases in soil moisture (40-300%) over long time (3-5 yrs). Increase in plant available soil moisture not investigated (~15).	Increased soil moisture (50-60%). Increase in plant available soil moisture not investigated (2).	Deeper mulches are more effective to increase soil moisture but beyond a point may cause other detrimental effects. No data to support irrigation saving claims.
	Reduced fertiliser application	Short term monitoring suggests slow mineralisation of mulches hence supply of nutrients (2).	Short term monitoring suggests slight increase in nitrates in the topsoil (2).	Rates of mulches and soil conditioners should not exceed nutrient requirements of grapevine.
Increased farm capital value	Increased soil health (soil biological, physical and chemical properties)	Tendency to increase SOM, reduce bulk density, soil strength over short term. Long term application should eventually improve soil health (~10).	Tendency to increase SOM in short term monitoring (2).	Application of mulches increased K levels (100-150%) in the soil and uptake by plants (50%) that has potential to reduce grape and wine quality.

Note: the figures in brackets represent the total number of trials that have meseaured/investigated that performance outcome out of total 27 field trials reviewed for this report.

Weed suppression

Addition of RO products as surface mulches can reduce the growth of weeds from 60 to 100%. Soil conditioners did not suppress weeds. The weed suppression effect of mulches decreased over time. Pasteurised mulches were more effective in weed suppression than composted mulches (as would be expected due to phytotoxic effects of pasteurised mulches), while composted mulches were more effective than standard practices of straw in many regions. Application of mulches without prior herbicide use had higher relative impact on weed suppression in the short term and thick mulches (>10 cm deep) were more effective in weed suppression. This performance benefit has the potential to reduce vineyard production costs by reducing herbicide use, and therefore provides the opportunity for reduced environmental impact and contribution to organic and/or environmental certification.

Yield and quality

The use of RO products in viticulture has produced variable results on fruit yield and quality. Most studies have found fruit yield and quality unaffected due to application of mulches and soil conditioners. Few field trials have found a slight increase in fruit yield and quality (ranging from 10-40%). Lower mulching rates (up to 10 cm) and soil conditioner rates (10 litres per vine) did not show any deleterious effects on fruit yield and quality. Whilst the absence of a negative impact on yield and quality is a valuable result, improvements in yield as well as quality will be highly regarded. Yield increases can only be quantified where cultural practices (such as bunch thining) are known and documented. Higher application rates of composted mulches and soil conditioners have shown deleterious effects on yield and quality.

Soil health

Mulching of vines consistently maintained lower soil temperatures and reduced fluctuations in soil temeperatures compared to unmulched vines. This is highly beneficial to reduce crop stress and improve productivity in hot climates. Few field trials have studied the impact on soil health parameters. These trials have not found significant changes in soil properties in the short term resulting from application of RO products. Application of RO products over time will eventually increase SOM, resulting in improved soil properties and soil productivity, and reducing land degradation. However, such performance outcomes have not been demonstrated in short term trials.

Nutrient availability

Two field trials have studied nutrient release from RO products over the short term. Pasteurised mulches were shown to cause a decrease in nitrate levels as expected in the short term. Recycled organics products release nutrients variably and slowly over 3-5 years after the decomposition of organic matter present in the RO products. Information on the release and availability of nutrients from application of RO products in agriculture under different environmental conditions is critical. This data will allow RO product application rate to be calculated considering crop nutrient requirements and environmental conditions without affecting grapevine yield and quality. This information is not known for Australian environmental conditions. Release and availability of major plant nutrients (N, P and K) from RO product applications is highly important in this regard.

Application rate

Application of thick mulches (greater than 10 cm) were found more effective in weed suppression and increased soil moisture. However, thick mulch applications or higher application rates of soil conditioners can potentially supply excess nutrients, promoting vegetative growth which can result in reduction in fruit yield and quality, or cause other deleterious effects. Selection of an optimum mulching depth that provides maximum benefit in terms of weed suppression and soil moisture increase without any detrimental impact on crop productivity is necessary. Nutrient budgeting is a necessary consideration when considering product specification and application rates.

Longevity of benefits

Mulches were shown to maintain the effect of soil moisture increase over a long time (3-5 years) while weed suppression effect decreased over time (after 6-12 months). This suggests that reapplication time of mulches should take into account these issues to maximise benefits of mulches to viticulture.

Recommendations

Use of RO products as surface mulches have demonstrated significant reduction in weed growth, reduced water evaporation from soil surface, produced more stable soil temperatures, and reduced crop stress. All these performance benefits would assist growers to maintain long term land and crop productivity, whilst potentially reducing the irrigation and the use of farm chemicals, hence reducing production costs.

Due to the short term funding of these projects, most performance benefits have been measured over one season whereas benefits from single and repeated applications of mulch are realised over a longer time frame. Many specific performance benefits have been studied in only a small number of field trials and over short term duration (Table 1) or results have not been statistically analysed. As a result the use of such performance data must be quantified with associated limitations. A number of important performance benefits have not been studied at all in these trials.

Long term and statistically significant data is required to demonstrate and quantify predictable performance benefits that can demonstrate cost-benefit advantage and therefore support increased demand. It is reccomended that a comprehensive, multisite, long term strategically designed R & D program be conducted that specifically targets vital performance benefits and covers the crucial gaps identified in Section 5. This program should use RO products of suitable and known specifications, to provide reliable performance data to inform valid cost-benefit analysis. Such a program may be supported by deliberately complementary demonstration trials and other strategies, which may be conducted concurrently on suitable vineyards in the grape production regions. These trials/strategies will help to inform RO products integration into farm management practices and provide complementary data to accelerate RO product uptake in the viticulture industry.

This study provides generic specifications of composted mulches and composted soil conditioners (Section 7.1) that can be used in viticulture to maximise benefits of RO products. This study also provides a structure for the consideration of performance benefits which will assist in the design of future trials. These issues are addressed in recommendations in Section 7.2. The provision of the Table 7.3 (Section 7.2) does not mean that all performance benefits should be studied in a single trial, nor does it mean all performance benefits needs to be studied in future trials. However, it is highly recommended that future trials should be designed in a way that specific performance benefit/s is/are studied thoroughly and over the long term (3-6 years) to reach conclusive results. Performance benefits that are considered to require attention in the future R & D program are prioritised below:

- Trials should be of relevant duration. Soils, climatic conditions, characteristics of recycled organics products and farm management practices are known and documented. Recycled organics products selected are of optimum characteristics to maximise agricultural performance and cost-benefit advantage.
- Reduced irrigation water usage - Quantification of the increase in soil moisture arising as a result of application of composted mulches and composted soil conditioners and evaluation of the relationship between increase in soil moisture and irrigation water savings in properly managed irrigation systems.
- Reduced fertiliser application – Quantification of the release and availability of major nutrients (N, P and K) for plant use through application of composted mulches and composted soil conditioners over time.
- Weed suppression duration– Quantification of suppression of weeds over time from different depths of composted mulches.

Section 1 How to use this report

1.1 Objectives of the report

The NSW Waste Boards market study carried out in 1999 identified that the highest potential market demand for recycled organics (RO) products close to the Greater Sydney Region is for viticulture. There is very little use of RO products in viticulture in NSW. Creation of demand in this market segment requires knowledge of performance benefits of RO products for this application. The development of a product specification designed to consistently meet the specific needs of this market segment and to maximise the cost/benefit advantage to growers, will provide market confidence and contribute to overcoming affordability barriers (Recycled Organics Unit, 2002).

The potential benefits of RO products in viticulture have been studied in Australia over the last five years using various varieties of composts and composted products. However, most of this research has not been peer reviewed or published, and is not readily accessible. Therefore the objectives of this report were to review relevant project reports, publications, presentations and articles in viticulture to:

- Establish baseline performance data for the use of RO products for viticulture application within the context of environmental factors and farm management systems;
- Review the methodology of previous trials, document key experimental design issues for applied field trials and to prioritise relevant monitoring parameters for the purpose of establishing the performance benefits and cost-benefit advantages of the application of RO products;
- Identify gaps in available data, thereby informing and prioritising future applied product application trials, and
- Inform the future development of performance-based RO product standards and application guidelines for the viticulture market segment.

1.2 Scope

The report reviews relevant project reports, publications, presentations and articles on RO product application in viticulture. Information reviewed will include (but not be limited to) studies conducted by NSW Agriculture Organic Waste Recycling Unit (OWRU), Agriculture Victoria (Institute for Horticultural Development), Agriculture WA, CSIRO Land and Water, and SA EPA.

1.3 Who is the report for?

This report firstly is for government policy makers who have involvement in the development of programs and initiatives to support the development of the recycled organics industry. Government support in this context aims to assist industry in maximising the diversion of compostable organic materials from landfill, to higher resource value applications.

This report is also useful for manufacturers of RO products who are seeking viticulture customers, and who invest in the development of RO products for the needs of specific customers or markets.

In particular, the report has been written for:

- Department of Environment and Conservation (NSW);
- Manufacturers and/or blenders of RO products;
- NSW EPA Waste Policy section;
- Marketers of recycled organics products;
- Waste educators;
- Industry consultants;
- Agriculture and Natural Resource departments of various State Governments; and
- Other relevant interstate and Commonwealth Government agencies.

1.4 How to use the report

The report is organised in ten sections. The first section lists the objectives of the report, who this report is for, how to use the report, terminology and how to cite the report.

The second section begins with a brief description of viticulture as a farm management system, provides information on costs involved, best and common management practices and brief introduction on opportunities of RO products application in viticulture.

The third and fourth sections of the report provide an assessment of the context of field trials in viticulture using mulches and soil conditioners. These sections report on spectfic variables affecting performance such as climate, soil types, irrigation/non-irrigation, irrigation water quality, RO product type, RO product quality, RO application rate and method and experimental design for product application trials. Performance outcomes arising from the use of RO products are listed under the following four categories: reduced risk of crop loss, increased revenue due to increased yield, reduced costs in farm management and increased farm capital value.

The fifth and sixth sections identify the gaps and limitations of the existing studies, provide conclusions and recommendations and recommends R & D priorities including methodology for product application trials. The seventh section provides basic product characteristics as recommended for viticulture market segment on the basis of current knowledge.

The eigth and ninth sections include the references and glossary.

1.5 Terminology

Terms used throughout this report have been officially adopted by the NSW Waste Boards in July 2000 in the form of the national reviewed Recycled Organics Dictionary and Thesaurus: Standard terminology for the recycled organics sector (Recycled Organics Unit, 2002a). This document is freely downloadable from http://www.rolibrary.com

Where possible, nationally accepted terms have been used in this report. Key terms and definitions are provided in the Glossary (Section 9).

1.6 How to cite the report

This report shall be cited in the following manner:

Recycled Organics Unit (2003). *The Recycled Organics Products In Intensive Agriculture Volume 2 - Viticulture: A Review of Recycled Organics Products Application Field Trials in Viticulture in Australia.* Recycled Organics Unit, internet publication: www.recycledorganics.com

Section 2 Introduction to viticulture

Viticulture is the term used to describe grape growing for production of various products particularly wine, dry grapes, fresh consumption (table fruits), juice for non-alcoholic consumption and concentrated juice. The viticulture industry is growing significantly throughout Australia. In NSW, grapes are grown throughout the state from Moree to Dayton, Tenterfield to Tumbarumba, and Port Macquarie to Mudgee (Antony Somers, District Horticulturist, NSW Agriculture, Tocal). The total area occupied by viticulture in NSW was 34,559 hectares that included grapes planted after 2000 harvest and were not fruit bearing at the time of survey (ABS, 2001).

The main viticulture regions in NSW outside the Sydney Metropolitan region and within 300-400 km radius of Sydney are Hunter Valley and Central West. The Hunter Valley currently occupies about 4,016 hectares under grape cultivation and the main areas are Singelton, Maitland, Muswellbrook and Cessonock (ABS, 2001). The Central-West region occupies about 3,815 hectares and the main grape growing areas are Mudgee, Cowra, and Orange and a small area in Bathurst (ABS, 2001). The total area under viticulture in the central-west has increased significantly since the last census in 1997 when it was about 779 hectares (only fruit bearing) (ABS, 1997). About 344 hectares are occupied in Yass and Young on the NSW South Coast. Smaller holdings exists in the Sydney metropolitan area occupying about 272 hectares and Macarthur and Illawarra regions occupying about 155 hectares mainly in Kiama, Shoalhaven and Wingeecarribee areas (ABS, 2001). Please note land covered by viticulture is based on growers' postal address hence does not always represent actual area for the location. This particularly applies to Sydney metropolitan area. It is highly unlikely that Sydney metropolitan area occupies 272 hectares under viticulture. Growers may have Sydney metropolitan postal address but the actual grape growing land, may exixt somewhere else.

Total grape production in 1997 in NSW was 209,900 tonnes (ABS, 1997). Of the total production of grapes about 83% (174,264 tonnes) were used for wine production, 12% (24,363 tonnes) for dry grapes and 5% (11,272 tonnes) for table fruits (ABS, 1997) suggesting over 80% of annual grape production is used for wine production.

2.1 Brief description of viticulture as a farm management system

The establishment of grape growing farms (vineyard) requires a whole farm plan that considers the farm's physical, financial and personnel requirements for now and the future (NSW Agriculture, 2002a). Farms should be planned and designed to protect the environment, allow for maximum agricultural use and profitability, and to ensure that farming practices have minimal impact on on-farm and off-farm natural resources.

The high cost of vineyard establishment makes it advisable to select an optimum site that meet the main criteria such as climate, availability of water, distance from industry facilities, topography, soil and the vineyard area (Browne, 1994).

A vineyard site needs gently undulating to flat topography, avoiding steep slopes that tend to be difficult to manage and vulnerable to soil erosion. Slopes to the north-east are preferred for maximum sunlight, warmth and protection from wind. Permanent plantings like grapevines are best planted in rows in a north to south aspect. Water flow following heavy rainfall should be diverted into dams and grassed areas. Buffer zones (areas of vegetated land) need to be established or left in place to protect sensitive environmental areas. Wind protection and screening of the whole farm and of individual large paddocks is recommended. Grapevines perform best in terms of fruit, productivity and ease of management – on red soils (Browne, 1994). The ideal soil is red loam to clay loam over a well structured red clay, but any well drained subsoil is suitable (Browne, 1994).

Vineyard land is prepared well before planting. The vines are grown on rows. The row spacing ranges from 3-3.3 m in hot areas to 2.8-3.0 m for cooler regions. All vine spacings are at 1.75 m or above to allow for 7 m panels with four vines per panel. End assemblies of these panels are either tie backs or diagonal stays. Rows of 300 m in length (10 rows/ha) are common in the hot areas and 200 m (17 rows/ha) in the cooler regions. A narrow, vertical 1.8 m high trellis is installed in the year of planting or a year after. The vine rootlings are trimmed to 2-3 buds and 10-20 cm root length before planting. Planting is carried as deep as possible with either water gun or shovel. In hot areas about 1,515 vines/ha are required for a 3.3 m x 2.0 m spacing and about 1,666 vines/ha for a 3.0 m x 2.0 m spacing in cool areas. Vines are best grown over the ground in year 1, trained to the trellis in year 2 and cropped in year 3 (Hedberg and Doyle, 1996).

2.2 Costs involved

The costs involved in establishing and running a vineyard will vary from place to place and management systems and are as follows:

- capital costs of establishing a vineyard,
- production costs, and
- overhead costs.

Peter Hedberg and Stephen Doyle of Orange Agricultural College, Sydney University have developed a budget for a 10 ha winegrape vineyard located at Mudge for the year 1996 (Hedberg and Doyle, 1996).

In this budget, the capital costs included costs of land, installing trellising, irrigation system and headworks, purchasing vines and provision of machinery and windbreaks. The budget estimated that up to $345,000/ha could be required to establish a 10 ha vineyard up to the first crop in the third season. Much of this cost was capital expense including machinery ($37,800), trellising ($55,000), irrigation includes operation and maintenance, pumping costs and water costs ($50,000), vines ($19,040) and irrigation headworks includes cost and set up of irrigation system ($30,000).

The production costs in this budget included costs for labour, vineyard planning, soil survey, land preparation, planting and training, soil management, pest and disease control, fertilisers, pruning, cultivation, irrigation (1-3 ML ha^{-1}), canopy management, harvesting and freight. At full production, growing costs have been estimated about $5,637/ha but can be as high as $6,400/ha or as low as $3,700/ha depending on management and scale of operation (Hedberg and Doyle, 1996).

Andrew Downs and Andrew Simc (2000) have prepared Horticultural Gross Margins for the Loddon Murray region, Victoria with trickle irrigation, mechanical pruning, and 5-6 ML ha^{-1} water use. The production costs in this budget have been estimated about $2,500/ha for winegrapes (grapes used for wine production) and $11,000 for table fruits (grapes used for raw consumption). The higher production costs of table grapes were due to higher costs required for water use, canopy management, harvesting, packaging and storage.

The yield and quality of winegrapes vary with regions, variety and management practices. A Grapevine Management Guide has been developed by NSW Agriculture (Small and Somers, 2002).

2.3 Best management practices

The best soil and weed management practices recommended in Grapewine Management Guide (Small and Somers, 2002) include use of cover cropping which involves growing any short duration crop preferabley leguminous and inter-row area applied with herbicide strip to maintain it free of weeds.

The best canopy management techniques for producing maximum fruit quality include shoot thinning, shoot positioning, bunch thinning, leaf plucking and summer hedging.

Fertilisers usually are used sparsely and vine leaf tissue analysis should be used as a guide to vine nutrition or fertiliser application.

The best irrigation method is the deficit irrigation strategy. This strategy aims to apply water only to the rooting depth of the crop and the soil is never watered beyond field capacity. Deficit irrigation, which takes into consideration evapotranspiration i.e. water evaporation from the soil and transpiration from the plants, applies less water than indicated by soil moisture monitoring without causing stress to plants. This irrigation method increases water use efficiency, reduce nutrient leaching, and has the potential to increase productivity of marketable fruit as this system supplies required amount of water needed for different vine growth stages.

Integrated pest and disease management and use of soft copper and sulphur based chemicals are preferred to be used for vines. Integrated pest and disease management includes combined use of chemical, cultural, mechanical and biological means such as crop rotation, good hygiene, crop monitoring, using beneficial organisms and protecting naturally occurring beneficial organisms and having breaks in crop production.

2.4 Common management practices

Discussions with Giola Small, Extension Viticulturist, NSW Agriculture, Wagga Wagga revealed that the viticulture industry is highly sophisticated and the common management practices may not vary from the best management practices unless it is necessary for a particular region and management system. For example for frost prone areas, farmers will not have cover cropping to avoid frost damage. The Riverina region where flood and furrow irrigation is practiced also may not have cover crops.

Leaf tissue analysis used as a guide to vine nutrition and fertiliser application is also not a common practice. Fertilisers are usually applied based on visual observation of the vine. However, most vineyards use integrated pest and disease management. Most new vineyards have drip irrigation systems and the average irrigation water requirement of a vineyard is about 2 to 5 ML ha^{-1}.

2.5 Opportunities for inclusion of RO products into viticulture production systems

As discussed in Volume 1, Section 3.2 (ROU, 2003) that intensive working of land used under intensive agriculture production systems is prone to loss of soil organic matter (SOM) resulting into soil structure decline, land degradation and loss of soil productivity. Similar consequences apply to viticulture production systems. Recycled organics products when applied to the soil surface as mulches reduce growth of weeds, evaporation of water from the soil surface and retains soil moisture. Recycled organics products also contain organic matter and nutrients, and when applied to the surface of the soil (surface mulch) or incorporated into soil (soil conditioners) organic matter decomposes slowly over time and integrates with soil's mineral component improving soil conditions. Consequently soil productivity and crop production is maintained and land degradation is prevented. The nutrients present in RO products are released steadily over time and become available for the growth of grapevine. The use of RO products in viticulture therefore has opportunities to address the following agricultural and environmental issues:

- Weed suppression resulting in reduced or avoiding use of herbicides,
- Reduced evaporation of water from soil surface. Increased soil moisture may lead to reduced use of irrigation water for irrigated conditions and water conservation in non-irrigated conditions,
- Sustained and long term release of nutrients for growth of vine reducing the use and manufacturing of chemical fertilisers,
- Reduced fluctuation of soil temperature resulting in reduced crop stress,
- Increasing soil organic matter leading to improved soil health and productivity, and prevention of land degradation, and
- Assist with conversion to organic production systems.

Section 3 Mulch application in viticulture

3.1 Description of field trials

This section provides information about known performance outcomes arising from use of RO products as surface mulches in viticulture. Mulch in this context refers to any composted and/or pasteurised products that are used as surface application around plants and are not incorporated into the soil. Mulch has at least 70% by mass of its particles with a maximum size of equal or greater than 16 mm as outlined in the Australian Standard for composts, soil conditioners and mulches (AS 4454, 2003).

A total of 27 relevant field trials have been carried out across Australia over the past decade. These trials have studied the benefits/effects of using RO products as surface mulch in viticulture. Information on these trials is available as mentioned below:

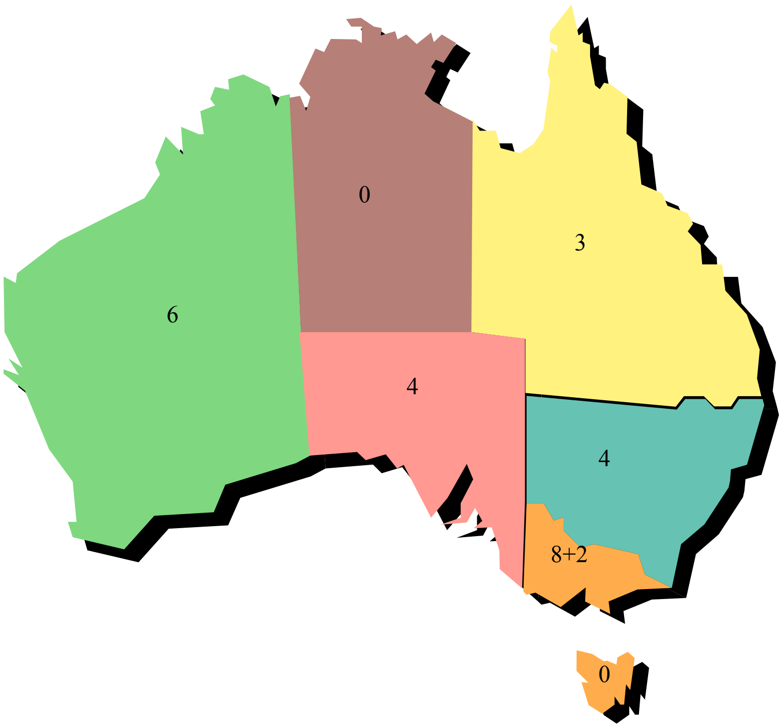
- The scope and location of these trials is identified in Table 3.1 and Figure 3.1;
- The documented performances outcomes are summarised in Table 3.2;
- A detailed description of each trial is provided as Appendix 1; and
- Specific and detailed performance outcomes are documented in Appendix 4.

This review focuses on the scientific trials that offer more reliable data, but also provides a description of demonstration trials that have been conducted.

Table 3.1 State-wise identification of field trials conducted across Australia using recycled organics products as surface mulches in viticulture.

Name of state	Number of trials	Recycled Organics Products used	Vine varieties tested
Victoria (scientific trials)	8	Composted mulches produced from garden organics and from garden organics and cattle manure	Pinot Noir, Chardonnay, Shiraz, Cabernet Sauvignon
Victoria (demonstration trials)	2	Composted mulches produced from garden organics and from plantation materials	Shiraz, Semillon
Queensland	3	Pasteurised mulches, composted mulches, vermicast+sugarcane trash	Cabernet, Flame seedless, Chambourcin
Western Australia	6	Composted mulches, blend of composted mulches and vermicast	Pinot Noir, Chardonnay, Shiraz, Cabernet Sauvignon
South Auistralia	4	Composted mulches from garden organics	Cabernet Sauvignon of various ages, Shiraz
New South Vales	4	Composted mulches, vermicompost and straw	Pinot Noir, Chardonnay, Shiraz, Cabernet, Semillon

Figure 3.1 Number of field trials conducted in viticulture using mulches in various states across Australia.



The soil where RO products are applied represents a biologically active system. Soils vary greatly, react differently under different environmental conditions and agricultural management systems, and undergo changes over time. Therefore the performance of mulches in agriculture production systems vary and is mainly controlled by the following factors:

- RO product characteristics (chemical, physical and biological characteristics),
- Environmental conditions (temperature, rainfall, soil types), and
- Farm management systems (crop variety and age, RO application method and rate, irrigation/non irrigation, irrigation water quality, use of fertilisers, herbicides and insecticides)

Given that performance of RO products in agricultural production systems is influenced by all these factors, information of these factors is essential in interpretation of performance results of RO products. The characteristics of RO products, environmental conditions and farm management systems used in viticulture field trials reviewed for this report is discussed below.

3.1.1 RO product type and quality

The viticulture industry compared to other agricultural industries is economically healthy and is expanding fast (Biala, 2000). The successful establishment and management of vineyards are important for the viability of the industry. Therefore reliable and suitable RO product quality is an important element in realising the demand potential in fast expanding viticulture industry.

Traditionally RO products as surface mulches have been used in agriculture to reduce water evaporation from the soil surface, suppress growth of weeds and reduce temperature fluctuations at the soil surface and these benefits are determined by the type and quality of RO products.

Type and quality of mulches depends mainly upon input materials (raw materials) and on the compost processing technology and management practices. The raw materials from which compost are produced can greatly effect the quality of mulches. For example mulches produced from animal manure, biosolids or garden organics will have higher nutrient content compared to products produced from woody or timber materials. Mulches produced from biosolids or Municipal Solid Waste (MSW) will tend to have higher heavy metal contents compared to garden organics or food organics. Mature composted mulches will contain high levels of stable organic humic compounds compared to pasteurised mulches which will have low levels of stable organic humic compounds. Poorly managed composts may not provide reliable pasteurisation of materials and are much more likely to contain weeds and pathogens.

The quality of mulches particularly the contents of organic matter and moisture, and toxicity, maturity, nitrogen drawdown index (NDI), heavy metals, and impurities (plant propogules, pathogens, stones, glass, plastics, etc.) is vital for viticulture. For example mulches with high impurities and heavy metal contents will not be suitable for the production of grapevines. Particle size and nutrient value in particular are also very relevant to application depth of mulch.

Australian Standards for composts, soil conditioners and mulches defines characteristics and qualities of RO products (AS 4454, 2003). New South Wales EPA guidelines (1997) for Use and Disposal of Biosolids Products documents permissible units with regards to the heavy metals for various land applications.

The RO products used as surface mulches in field trials, reviewed for this report were mainly: composted and pasteurised garden organics; vermicasts; vermicompost; and blends of composted and vermicast products and straw and sugarcane trash used as standard mulches in some areas. Most of the reports did not provide the physical and chemical characteristics of mulches, placing significant limitations on the value of the findings. The chemical quality of mulches included in some reports is provided in Appendix 2, some meet the requirements of mulches and vermicasts as per Australian Standard AS 4454 (2003), the exception being some products used in trials in Queensland and New South Wales, which do not. Unfortunately, only 9 of the 27 trials reviewed provided any detail of the characteristics and quality of the mulches used. Information on such basic characteristics as particle size is undocumented in the vast majority of studies.

The vermicast used in Queensland Trial 1 were produced from pig manure and sugarcane trash and the levels of copper (Cu) and zinc (Zn) were equal to 540 and 1023 mg kg^{-1}. The levels of Cu and Zn were higher than contaminant Grade A product though were within the limits of contaminant Grade C product according to NSW EPA Guidelines for Use and Disposal of Biosolids Products (NSW EPA, 1997). The levels of Cu and Zn in contaminant grade A products should not be greater than 100 and 200 mg kg^{-1} and for contaminant Grade C should be below 2000 and 2500 mg kg^{-1} dry weight basis (NSW EPA, 1997). Although the contaminant grade C products are suitable for agricultural land application but higher heavy metal contents than contaminant Grade A may not be ideal for high value fruit crop such as grapevine. The levels of Cu and Zn should be monitored in soils, vines and grapes when RO products containing the levels of Cu and Zn higher than contaminate Grade A are applied to vinegrapes. The levels of toxicity of composted mulches used in Trial 1 were also slightly high (58%) than required for composted mulches (≥60%) as per AS 4454 (2003).

The composted mulches and vermicompost used in New South Wales trials did not provide complete chemical analyses according to requirements of AS 4454 (2003), particularly the levels of organic matter, toxicity, and boron (B). In this case, the vermicompost products were produced from grape marc and other materials (unspecified) and the levels of Cu and Zn were 743 and 993 mg kg^{-1} and were again above the limits of contaminant Grade A but within the limits of contaminant Grade C. The levels of Cu and Zn in soils, vines and grapes should be monitored if RO products with higher levels of Cu and Zn than contaminate Grade A are applied to vines.

In both cases (Queensland and New South Wales trials) it is not clear if the levels of Cu and Zn in vermicast/vermicompost were expressed on dry or wet weight basis. If the results were provided on wet basis and when converted to dry weight assuming vermicast/vermicompost had 50% moisture content (vermicast used in Queensland trial had 46% moisture content), the levels of Cu and Zn will be doubled, though still remain within contaminant Grade C limits.

It is not possible to extend the performance data from specific (and unknown) products to mulches in general. This places significant limitations on the use of existing data for reliable cost benefit analysis or performance claims.

3.1.2 Environmental conditions

The variation in environmental conditions such as climate (rainfall and temperature), soil types and properties will have varying effect on the performance outcomes of mulches used in viticulture. Therefore this information is important to accurately interpret the results of performance outcomes of RO products from field trials. For example Dala and Chan (2001) has reported more rapid decomposition of SOC in tropical regions than in more temperate regions suggesting RO products (which are source of organic carbon/organic matter) will follow similar trend i.e decompose faster in warmer than in cooler climate hence the effect of RO products applied at same rate may last longer in cool compared to warm climates. Evaporation is also normally higher in hotter, drier areas, where the benefits of mulch may be more pronounced. In relation to soils, the application of mulches on clayey soils with restricted drainage has the potential to cause waterlogging due to reduced water evaporation from the soil surface (Biala, 2001), therefore we cannot assume that the application of mulch is always, necessarily beneficial.

Some reports have provided reasonable information on environmental conditions that were specific to the trials undertaken (Appendix 1). The data available on environmental conditions from this review suggests that mulches have been tested in a range of climatic conditions from hot to cool, and dry to wet and on varying soil types ranging from light soils (sandy, sandy loam having high infiltration rates) to medium to heavy soils (clay loam to medium to heavy clay with drainage restrictions). This range of information will be beneficial in the future development of performance based product specifications and application guidelines for viticulture.

3.1.3 Agricultural management practices

Different vine varieties show varying response to mulch treatments as do vines of different age. The studies reviewed have covered a range of vine varieties such as Shiraz, Pinot Noir, Chardonnay, Traminer, Semillon, Cabernet Sauvignon and Chambourcin. Trials performed have varied from region to region and have included young as well as established vines (6 months to 20 years old).

The vinegrape belongs to species *Vitis vinifera* which has various varieties. The characteristics of vine varieties such as growth, maturity and production, diseases, etc. varies among varieties. Mr Antony Somers, District Horticulturist with NSW Agriculture at Tocal provided information on different vine varieties grown in New South Wales paricularly Sydney and surrounding areas.

The main vine variety grown for raw fruit consumption within Sydney metroploitan area and surrounding Sydney areas such as Hunter Valley, Mudgee and Orange is Black Musket. The white and red grapevine varieties grown for wine production within 400 km radius of Sydney particularly in Hunter Valley, Mudgee, Cowra, Orange and Southern highlands are Semillon, Chardonnay and Verdelho (white grapes) and Shiraz, Cabernet Sauvignon and Merlot (red grape varieties).

Application of mulches at different rates (low or high) will have considerably varying effect on the performance of grapevines. As discussed previously that the main role of mulches is to suppress weeds, to retain soil moisture and, to lesser extent mulches are used as source of nutrients. Higher rates of mulches may have greater effect in weed suppression and soil moisture retention but at same time an excessively thick mulch layer may provide an ideal microenvironment for diseases, restrict further fertilizer side dressings, and N may be lost from the soil by denitrification if the soil is too wet beneath the mulch. Deeper mulches, paricularly those containing a proportion of fine particles can "suffocate" soil by inhibiting gaseous exchange, and may even reduce water penetration by absorbing moisture before it can reach the soil.

The field trials reviewed for this volume of the report have used mulches at various depths ranging from 1, 2.5, 5, 7.5, 10 and 15 cm (Appendix 1). Width of mulch application has also varied from 50 cm (0.5 m) to 80 cm (0.8 m). Total volume (m^3 ha^{-1}) or weight (t ha^{-1}) of mulch applied per hectare depends on the effective area covered by mulch application which in turn depends on number of vines per hectare and distance between vines in a row or number of rows in a hectare and the width of a row. For example application of mulch to 10 cm depth and 50 cm width will be equal to about 150 m^3 per hectare (Appendix 3). Conversion of mulch application depth and width to volume of mulch applied per hectare is provided in Appendix 3.

The standard farming practices may mask the effects of mulch application to an agricultural system. For example application of herbicides prior to the application of mulches may not demonstrate weed suppressive effect of mulch to full extent. In relation to soil water, the application of mulches under non-irrigated conditions may make rainfall water available to plants for longer time due to reduced evaporation from the soil surface. The standard farming practices including use of insecticides or herbicides were unchanged in most trials. The standard fertiliser practices were varied in some trials. It appears that most trials were irrigated and only few were non-irrigated. The quality and source of irrigation water were not provided in any report.

3.1.4 Experimental methodology

The long term R & D program and appropriate experimental methodology including experimental design and monitoring requirements are essential to back up performance benefits of RO products in intensive agriculture. The statistically significant performance benefits from research trials based on appropriate experimental design (replicated, randomised and having control for comparison) and comprehenssive monitoring requirements provide strong scientific base to validate the results.

All scientific trials reviewed for this volume had appropriate experimental design including replication, randomisation and control. Most field trials used replicated randomised block experimental design and a few have used Latin Square and Split Plot as well. The monitoring parameters and methods of trials varied significantly and have been compromised in many cases. The majority of trials have monitored performance benefits such as crop growth, fruit yield and quality, soil moisture and weed suppression but in most cases results have been derived from monitoring a single growing season, which is not sufficient for reaching scientific conclusions, particularly in relation to performance and cost/benefit data in agricultural production systems using RO products. Many performance benefits were measured as one of the parameters or as a side issue in these trials.

A few field trials have monitored nutrient availability, frost risk and soil health parameters such as soil biological, physical and chemical properties. The potential performance benefits such as diseases suppression, crop stress, time of crop growth stages and maturity, and wine quality were not monitored in any of these field trials.

3.2 Documented performance outcomes

The results of 27 field trials conducted throughout Australia have been reviewed for the viticulture. The detailed results of performance benefits of RO products as surface mulches have been provided in Appendix 4 and summary of these results are presented in Table 3.2. The performance outcomes have been presented under the following four performance categories:

- Reduced risk of crop failure,
- Increased revenue (from increased yield, improved produce quality and time to market),
- Reduced costs in farm management (reduced water usage, fertilizer application, farm chemicals), and
- Increased farm capital value (soil health).

Table 3.2 Summary of performance outcomes of recycled organics products used as surface mulches in viticulture.

Trial code and treatments	Reduced risk of crop failure	Increased revenue (yield, time to market, produce quality)	Reduced costs in farm management (water usage, fertiliser application, reduced farm chemicals	Increased farm capital value (soil health)
VIC-KW-2000 Control - bare ground S10-Straw10 cm layer applied as surface mulch FM10-Fine mulch applied 10 cm deep as surface mulch CM10-Coarse mulch applied 10 cm deep as surface mulch		Shoot vigour - No increase after first season monitoring Grape yield - No increase after first season monitoring.	Weed growth - Reduced significantly at both vineyards that were confined to young vines only.	
VIC-KW-2001 Continuation of VIC-KW-2000 trials established in 1998 C-Control - bare ground S10-Straw-10 cm layer applied as surface mulch FM10-Fine mulch applied 10 cm deep as surface mulch CM10-Coarse mulch applied 10 cm deep as surface mulch	Delayed budburst not observed Increased levels of soil K that increased crop K uptake.	Vine vigour- No increase on young & established vines after six weeks period. Pruning weights & Fruit yield - Unaffected Bunch wt - Unaffected 100 berry wt - Unaffected Grape juice quality - Unaffected Brix (%), pH, and titrable acids. K levels in petioles - Increased significantly (above adequate level).	Weed growth - Reduced significantly (71-87%) for all mulched treatments. Soil moisture - Increased significantly (250-300%) for all mulched treatments. Composted mulches were more effective than straw.	Soil conditions -No significant changes in the short term {soil sampled at 0-15 cm depth (Dec.2000) after two mulch applications except levels of K. Soil K levels - Increased significantly in the soil (80-150%) from near deficient (<100 mg/kg) to near adequate (>150 mg/kg). Fine mulch was most effective. Soil K levels >250 mg/kg may cause problem with red wine quality.

Table 3.2 Summary of performance outcomes of recycled organics products used as surface mulches in viticulture.

Trial code and treatments	Reduced risk of crop failure	Increased revenue (yield, time to market, produce quality)	Reduced costs in farm management (water usage, fertiliser application, reduced farm chemicals	Increased farm capital value (soil health)
VIC-SS-2001	Frost risk - Not observed	Grape yield, Bunch Number. & Quality (Baume) - Unaffected	Soil moisture - Increased significantly 100-150% for mulched treatment.	Soil heat flux and soil temperature - significantly different
VIC-GPMS-2000 Demonstration trial, not replicated M-Composted mulch applied 7.5 cm deep and 50 cm wide UM-ummulched		Bunch/berry numbers-No influence. Fruit yield - Increased by 10-12% Fruit quality - pH and brix Unaffected Shrivelled berries- Less shrivelled Vine stress- suffered less stress during hot weather. Leaf colour was slightly better. Fruit sap elemental analysis-Unaffected.	Soil moisture retention - Observed better. Weed suppression - Noted Irrigation water usage- Reduced during 4 months of irrigation monitoring. Mulched row was not irrigated once. About 20,000 lt of water can be saved on one watering of one block (2500 vines @ 2lt/hr for 4 hrs)	
VIC-GCR-1999 Demonstration trial, not replicated		New growth and node length –More on mulched rows. Grape nodules - Developed earlier on mulched vines.	Weed control - Positive response.	
VIC-DBPP-2000 Demonstration trial, not replicated C-control M-Composted mulch applied 10 cm deep and 10 cm wide.		Stem diameter - Increased about 5% after 20 & 70 months of mulch application. Vine vigour - Increased by 12%. Bunch and berry weight - Increased by 17.6 % av. bunch wt. Av. berry wt - Increased Sugar content - Higher		

Table 3.2 Summary of performance outcomes of recycled organics products used as surface mulches in viticulture.

Trial code and treatments	Reduced risk of crop failure	Increased revenue (yield, time to market, produce quality)	Reduced costs in farm management (water usage, fertiliser application, reduced farm chemicals	Increased farm capital value (soil health)
QLD-JB-2001 Trial 1 C-control V/ST-vermicast/sugar trash as surface mulch (10lt/vine) PM- Pasteurised mulch applied to 15 cm depth as surface mulch CM- Composted mulch applied to 15 cm depth as surface mulch CSC- Composted soil conditioners as fertilisers	Frost damage was caused by late frost in October, 2000. Damage ranged from dieback of new shoots to more or less severe splitting of the lower part of the stem. Frost damage was highest for pasteurised mulch and nil for composted mulch compared to control. Number of live vines decreased 30% while number of vines lost increased 55% for pasteurised mulch compared to control.	Measurements taken 10 months after mulch/soil conditioner application. Vine vigour - Statistically not different. Grape yield -Statistically not different	Weed growth - Suppressed under vine. Percentage ground cover reduced about 80%, 4 months after application in V/ST & PM. Soil moisture (%) from one off measurement - Increased at 0-30 & 30-60 cm depths. All organic amendments increased soil moisture content 30-50% in the topsoil and up to 65% in the subsoil. Nutrient release - No difference between treatments.	Soil chemical properties- Measurements taken 10 months after mulch/soil conditioner application at 0-30 cm depth. Most properties did not change except K levels. Soil potassium (mg/kg)- Increased 100-150% in PM & CM
QLD-JB-2001 Trial 2 C-control PMA- Pasteurised mulch autumn application applied at 12.5 cm depth as surface mulch PMW- Pasteurised mulch winter application applied at 12.5 cm depth as surface mulch PSC- Pasteurised soil conditioners as fertiliser		Measurements taken 10/12 months after mulch/soil conditioner application. Vine vigour - Statistically not different. Grape yield – No yield measurements were not taken because fruits were damaged by birds.	Weed growth - Suppressed under vine. Reduction in % ground cover under mulched application 80-90% after 3.5-5 months and 50-60% after 6-7.5 months Soil moisture (%) one off measurement taken October 2000). Statistically not significant. Nutrient release - Six measurements taken during September 2000 to April 2001. No difference between treatments	Soil chemical properties - Measurements taken 10 months after mulch/soil conditioner application at 0-30 cm depth. Most properties did not change except levels of K and SOM increased. Soil organic matter (%w/w)- Increased slightly 5-20% for mulched treatments. Soil potassium (mg/kg)- Increased about 100% in mulched treatments Soil microbial activity and population- Active bacterial and fungal biomass was higher for control while total bacterial & fungal biomass was higher in mulched treatments.

Table 3.2 Summary of performance outcomes of recycled organics products used as surface mulches in viticulture.

Trial code and treatments	Reduced risk of crop failure	Increased revenue (yield, time to market, produce quality)	Reduced costs in farm management (water usage, fertiliser application, reduced farm chemicals	Increased farm capital value (soil health)
QLD-JB-2001 Trial 3 C-control PM10- Pasteurised mulch 10 cm deep application as surface mulch PM5- Pasteurised mulch 5 cm deep application as surface mulch		Measurements taken 6 & 18 months after mulch/soil conditioner application. Vine vigour - Slight increase in shoot length and stem diameter. Grape yield- No yield measurements were taken because fruits were damaged by birds.	Weed growth- Measurements not undertaken due to application of herbicide. Soil moisture in top 30 cm depth (%)- Statistically not significant. Nutrient release – Due to budgetary restrictions, nutrient release was not measured for this trial.	Soil chemical properties - Measurements taken 16 months after mulch/soil conditioner application at 0-30 cm depth. Most properties did not change except levels of K and SOM increased. Soil organic matter (%w/w)- Increased about 15% in PM10 Soil potassium (mg/kg)- Increased slightly (15%)
WA-BP-2001 Trial 1 C - Bare ground CM2.5 - Composted mulch 2.5 cm deep as surface mulch CM5 - Composted mulch 5 cm deep as surface mulch CM7.5 - Composted mulch 7.5 cm deep as surface mulch S - Standard straw mulch @ 2 kg/m of vine row		Vine growth - Straw had less effect than composted mulch. Trunk diameter (mm) after 5 months - Increased slightly (1-2%). Wine grape yield - Lower mulch rates had higher grape yield (15-20%. Lower mulch rates had higher vine growth and grape yield. Straw was less effective. Fruit quality- unaffected	Soil moisture – Composted mulch was more effective than straw mulch.	
WA-BP-2001 Trial 3 C-Control B1-Blend 1 of composted mulch & vermicast 1 cm deep as surface mulch in 0.6 wide strip B2-Blend 2 of composted mulch & vermicast 1 cm deep as surface mulch in 0.6 wide strip B3-Blend 3 of composted mulch & vermicast 1 cm deep as surface mulch in 0.6 wide strip B4-Blend 4 of composted mulch & vermicast 1 cm as surface mulch in wide 0.6 strip		Yields, bunch counts and 100 berry weights and quality measurements were taken. No significant differences.		

Table 3.2 Summary of performance outcomes of recycled organics products used as surface mulches in viticulture.

Trial code and treatments	Reduced risk of crop failure	Increased revenue (yield, time to market, produce quality)	Reduced costs in farm management (water usage, fertiliser application, reduced farm chemicals	Increased farm capital value (soil health)
WA-BP-2000 Trial 4 C - Bare ground CM2.5 - Composted mulch 2.5 cm deep as surface mulch CM5 - Composted mulch 5 cm deep as surface mulch CM7.5 - Composted mulch 7.5 cm deep as surface mulch S - Standard straw mulch @ 2 kg/m of vine row.		Measurements for trunk diameter were taken immediately after trial establishment Grape yield- Increase statistically not significant. Fruit quality- Unaffected		
WA-BP-2001Trial 5 C - Bare ground CM2.5 - Composted mulch 2.5 cm deep as surface mulch CM5 - Composted mulch 5 cm deep as surface mulch CM7.5 - Composted mulch 7.5 cm deep as surface mulch S - Standard straw mulch @ 2 kg/m of vine row		Wine grape yield - Measurement taken in Feb. 2001. 100 berry wt (g) - Increased berry weight and average bunch weight with composted mulch (20-40%). Fruit quality – Total soluble solids, juice pH and acidity increased by 25, 23 and 34% respectively for highest mulch rate. Higher mulch rates were more effective. Straw was less effective.		
WA-BP-2001 Trial 6		Initial trunk diameter were recorded. Trial was not harvested		
WA-BP-2001 Trial 7		Initial trunk diameter were recorded First harvest was not yet recorded.		

Table 3.2 Summary of performance outcomes of recycled organics products used as surface mulches in viticulture.

Trial code and treatments	Reduced risk of crop failure	Increased revenue (yield, time to market, produce quality)	Reduced costs in farm management (water usage, fertiliser application, reduced farm chemicals	Increased farm capital value (soil health)
SA-JB-1999a C-Control CM1- Composted mulch 1 cm deep as surface mulch CM5- Composted mulch 5 cm deep as surface mulch CM15- Composted mulch 15 cm deep as surface mulch S20- Straw 20 cm deep as surface mulch		Vine growth- Increased after seven weeks of mulch application Shoot length (cm)- Increased 65% Prunings weight (g)- Increased about 50%. Fruit yield- Increased 5 months after mulch application. Grape yield (kg/vine)- Increased about 200%. Bunch number from young vines (per vine)- Increased 100% 50 Berry weight (g)- Increased 23% Fruit quality-Unaffected	Soil moisture (%) – Increased (300-100%) seven weeks after mulch application under vines soil moisture at 5 cm and 10 cm depths. 5 cm mulch was as effective as 20 cm straw in soil moisture conservation.	
SA-JB-1999b Shiraz 5 yo SA-JB-1999 Trials established in 1996 continued Control (no mulch) CM1- Composted mulch applied 1 cm deep as surface mulch CM5- Composted mulch applied 5 cm deep as surface mulch CM15- Composted mulch applied 15 cm deep as surface mulch S20- Straw applied 20 cm deep as surface mulch Control		Vine growth within six weeks of mulch application Shoot growth-Improved with mulch Prunings weight-Increased 2 times for 5 cm mulch compared to control. Fruit yield- Increased after 18 months of mulch application Grape yield (kg/vine)- Increased 35% for 15 cm composted mulch. Fruit quality- Decreased brix% and juice pH	Soil moisture % at 0-10 cm soil depth- Increased 100-300%. Highest increase was measured for highest mulch application rate.	

Table 3.2 Summary of performance outcomes of recycled organics products used as surface mulches in viticulture.

Trial code and treatments	Reduced risk of crop failure	Increased revenue (yield, time to market, produce quality)	Reduced costs in farm management (water usage, fertiliser application, reduced farm chemicals	Increased farm capital value (soil health)
SA-JB-2001a C-Control (no mulch) CM2.5- Composted mulch 2.5 cm deep as surface mulch CM5- Composted mulch 5 cm deep as surface mulch CM10- Composted mulch 10 cm deep as surface mulch		Vine growth-Increased within six months of mulch application. Vine trunk diameter (mm)- Increased about 35% Yield of table grapes (kg/vine)- 4 months after mulch application. Increased significantly (16%) with improved berry size.	Soil moisture (%)- Reduced by 20% in 0-10 cm soil depth.	Soil properties – Improved within 12 months of mulch application Water infiltration (mm/hr) - Increased 4 times (data not provided) Earthworm activity-Increased Earthworm density (nos/m^2) – Increased significantly 4-5 times in the soil under mulch. Soil strength (MPa)-Reduced (15%) below the levels considered critical for root penetration.
SA-JB-1998 & 1999b Cabernet Sauvignon 6 months old C-Control (no mulch) CM5-Composted mulch 5 cm deep as surface mulch		Vine growth- Increased 4 months after mulch application Trunk diameter (mm)-Increased 50%		
SA-JB-2001b Cabernet Sauvignon 1 yo C-Control (no mulch) CM7.5- Composted mulch 7.5 cm deep and 50 cm wide as surface mulch		Vine growth-Improved within 6 weeks. Mulches reduced stresses associated with establishment of vines on a deep sandy soil. Shoot length (cm)-Increased 65% within 6-7 weeks Fruit yield- 1997 harvest Increased 5 months after mulch application. Grape yield (kg/vine)- Increased about 250%. Bunch number (per vine)- Increased 100% 50 Berry weight (g)- Increased 30% Fruit quality-Unaffected		

Table 3.2 Summary of performance outcomes of recycled organics products used as surface mulches in viticulture.

Trial code and treatments	Reduced risk of crop failure	Increased revenue (yield, time to market, produce quality)	Reduced costs in farm management (water usage, fertiliser application, reduced farm chemicals	Increased farm capital value (soil health)
SA-JB-2001b Cabernet Sauvignon 2 yo Continuation of SA-JB-2001b trial C-Control (no mulch) CM7.5- Composted mulch 7.5 cm deep and 50 cm wide as surface mulch CM15- Composted mulch 15 cm deep and 50 cm wide as surface mulch		Measurements for harvest 5, 2001 and 7.5 cm mulch application Trunk diameter (cm)-Increased 60% Fruit yield (kg/vine)-Increased 29% Bunch number (per vine)-Increased 10% Bunch weight (g)- Increased 14% Berries (nos/bunch) Increased 12% Fruit quality-Unaffected	Soil moisture (% at 0-30 cm depth) at harvest 5, 2001-Increased 40-70%	Water infiltration (mm/hr)-Increased 100-150% Soil strength (MPa, at 50 cm depth)- Reduced significantly (23%)
NSW-PW-2001 Tumbarline C-Control (no mulch) CM10-Composted mulch applied 10 cm deep and 50 cm wide as surface mulch V1+S20-Vermicompost+straw as surface mulch 50 cm wide S20-Wheaten straw one bale applied to 20 cm depth and 50 cm wide as surface mulch.			Weed cover (% weed cover) – Reduced highly significantly in composted mulch (93%) compared to other treatments.	
NSW-PW-2001 Arrowfield C-Control (no mulch) CM10-Composted mulch applied 10 cm deep and 75 cm wide as surface mulch V1S20-Vermicompost+straw as surface mulch (Vermicompost applied 1 cm deep and 75 cm wide and covered by 20 cm deep 1 wheaten straw bale). S20-Wheaten straw one bale applied to 20 cm depth and 75 cm wide as surface mulch.		Fruit yield- Unaffected for both varieties Fruit quality- Unaffected for both varieties	Weed cover (% weed cover) – Pinot Noir site reduced significantly 60-90%) for all treatments compared to control. Chardonnay site reduced highly significantly (50-80%) for all treatments compared to control.	

Table 3.2 Summary of performance outcomes of recycled organics products used as surface mulches in viticulture.

Trial code and treatments	Reduced risk of crop failure	Increased revenue (yield, time to market, produce quality)	Reduced costs in farm management (water usage, fertiliser application, reduced farm chemicals	Increased farm capital value (soil health)
NSW-PW-2001 Tullamour C-Control (no mulch) CM10-Composted mulch applied 10 cm deep and 50 cm wide as surface mulch V1S20-Vermicompost+straw as surface mulch (Vermicompost applied 1 cm deep and 50 cm wide and covered by 20 cm deep 1 wheaten straw bale). S20-Wheaten straw one bale applied to 20 cm depth and 50 cm wide as surface mulch.		Vine vigour- Unaffected Fruit yield- Unaffected Fruit quality- Unaffected	Weed cover (% weed cover) – Reduced significantly (85%) in Vermicompost+straw treatment. Soil water- soil moisture tension monitored at 10 and 50 cm depths. Due to frequent rainfall soil was kept wet most of growing period. Soil moisture characteristics for two dry spells observed that soil under mulched treatment tended to dry more slowly than soil in the control plots. Soil temperature – Measured at 5 and 20 cms depths. At both depths soil temperature fluctuations was less for all mulched treatments compared to control. Composted mulched treatment had consistently 2-3^{o}C higher temperature compared to both straw mulch treatments.	Soil health Pre-treatment microbial activity was significantly higher (20 times) in RO products than at 0-15 cm soil. End of trial soil microbial activity (0-10 cm depth)-Unaffected End of trial soil microbial activity (0-2.5 cm depth)- Increasing trend under mulched treatments. Only V1S20 had significantly higher microbial activity compared to control. Soil chemical properties and nutrients (0-10 cm depth) Statistically not different than pre treatment soil. Soil bulk density (g/cm3)- Decreasing trend at 0-5 and 5-10 cm depths
NSW-PW-2001 Orange C-Control (no mulch) CM10-Composted mulch applied 10 cm deep and 50 cm wide as surface mulch V1S20-Vermicompost+straw as surface mulch (Vermicompost applied 1 cm deep and 50 cm wide and covered by 20 cm deep 1 wheaten straw bale). S20-Wheaten straw one bale applied to 20 cm depth and 50 cm wide as surface mulch.		Vine vigour- Unaffected Fruit yield- Unaffected Fruit quality- Unaffected	Weed cover (% weed cover) – Reduced highly significantly (80-100%) in all treatments compared to control No prior herbicide application.	

3.3 Discussion of results

3.3.1 Reduced risk of crop failure

The main reasons for failure of a grape crop like other horticultural crops is due to incidence of pest and diseases, frost damage caused in cool climates and crop stress due to hot climates and low soil moisture availability in non-irrigated conditions.

3.3.1.1 Suppression of diseases

None of the field trials reviewed for this report have monitored suppression or incidence of grapevines pest and diseases associated with the application of mulches.

The international literature reviewed by NSW Agriculture (2002b) on soil carbon sequestration utilizing RO products have reported that the diverse microbial populations in RO products and the influence of RO amendments on soil microbial populations have shown suppression of soil-borne plant diseases. Similar findings have been reported by Biala (2000) who has reviewed international literature on use of compost in viticulture.

Incidence of botrytis or bunch rot of grapes, the major disease in wine grape production in Newzealand, was less on mulched plots (composted mulches were produced from vineyard prunings, winery waste (marc), garden organics, pine bark and animal manure) than unmulched plots (Mundy and Agnew, 2002).

The phenomena for disease suppression are complex and can be due to range of different mechanisms such as production of antibiotics during the maturation process, increased competition for nutrient and carbon resources through higher microbial activity resulting from application RO products or induced systematic resistance in the plants (Hointink and Fahy, 1986; Wong, 2001).

All RO products are not equally disease suppressive and the suppression is dependent upon factors such as temperature, moisture, pH and maturity of RO products (de Ceuster and Hointink, 1999; Wong, 2001). The literature reviewed by Biala (2000) on use of compost in viticulture has reported that to date it is not known which RO products (e.g mature or immature) will show disease suppressive properties and is particularly difficult when these products are produced from diverse raw materials. Hoitink and Grebus (1994) have found immature composts served as a food source for pathogens, while excessively stabilised organic matter did not support the activity of biocontrol agenets. Hointink and Boehm (1999) have produced highly suppressive RO products by adding microbial antagonists such as *Trichoderma*, *Flavobacterium* and *Enterobacter* species.

Peter Fahy and his team looking for disease suppression against Pythium and Rhizoctonia diseases in surveys of potting mixes and potting mix components over time and from a range of composters and nursieries have defined the best standards to maintain consistent disease suppression (Fahy, 1997) The important characteristics of potting mixes responsible for disease suppression identified in the surveys were electrical conductivity (EC), pH, nitrogen drawdown index (NDI), high microbial activity and air filled porositry (Fahy, 1996 internet publication: http://www.ngia.com.au/np/np97_3.html).

Inappropriate use of RO products may also have detrimental effects on plant health. Biala (2000) has cited that high levels of nitrates in the soil has the potential to enhance the incidence of fungal disease Botrytis rot or grey mould of grapevines which is why the use of large quantities of nitrogen-rich RO products may result in an increase of this disease.

Pests and diseases cause a significant damage to agriculture worldwide every year. Production of RO products that reduce incidence of pests and diseases will provide two fold incentive to grapevine growers to include RO products in farming practices. Firstly use of disease suppressive RO products reduce risk of crop failure and loss of production. Secondly reduced use of farm chemicals to prevent diseases result in reduced production costs, and produce grown with reduced or without chemicals has the potential to attract a premium price in the market.

Future trials should monitor the incidence of pest and diseases, particularly in relation to the potential for increased yield and quality.

3.3.1.2 Crop stress

Please note that no scientific field trials reviewed for this report have monitored effect of mulch application on reduced risk to crop from hot weather or water stress.

Water stress affects the grapevine in different ways depending on the vine’s stage of development. Dry conditions largely affect on overall development of canopy and crop such as irregular budburst, short shoots, fewer flowers and inhibit root growth during early stages of crop development (Coombe and Dry, 1992). The effects of water stress lessen when berries enter their lag phase and shoot growth slows, after which the main effect of severe stress can be delay in ripening (Coombe and Dry, 1992). Most of new vineyards are irrigated. The water stress conditions apply to those vineyards, which are not irrigated or where irrigation water may not be available for various reasons during critical vine growth stages .

Composted mulches (made from garden organics) applied at 7.5 to 10 cm depth in a irrigated **demonstration trial** in Victoria and established on rich red volcanic soils observed 6 yo Shiraz suffered less stress during hot weather (Greenspace Processing and Marketing Systems, 2000). This trial also observed that mulched berries shriveled less compared to unmulched berries. Although this was a demonstration trial results of which cannot be used to prove the performance benefit but it was the only trial that has monitored crop/fruit stress during hot weather.

Crop stress during crop and fruit development stages has the potential to reduce fruit production and quality, consequently affecting wine production and quality, though scientific trials would be required to confirm these results. The potential reduction in crop stress as a result of mulch application provides growers an incentive to include RO products in farming practices.

3.3.1.3 Frost risk and delayed bud burst

Freeze injury is one of the main limiting factors to crop production and distribution of horticultural crops in cooler climates and is considered accounts for greater losses of fruits than any other environmental and biological factors (Rodrigo, 2000).

It is well known that the use of mulches in frost prone areas can increase the severity of frost damage if vines are trained low (Coombe and Dry, 1992). Discussions with Roy Menzies, Research Horticulturist, NSW Agriculture explained that bare soil absorbs heat during day time and radiates it back overnight keeping air temperatures around tree canopy slightly higher hence reduces risk of frost damage in cooler climates. This phenomena works in opposite way when a mulch layer is applied under vines. Mulch prevents heat absorption during day time keeping soil temperatures few degrees (2-3^{o}C) lower under mulched vines. Over night under vine mulch do not radiate heat back to canopy therefore has the potential to increase frost risk. This may be the reason that low trained vines are more prone to frost damage.

The cooler soil temperatures under mulches in early spring can also delay bud burst past the most frost prone period (Wilkinson, 2001). Although the delayed bud burst can be an advantage in frost prone areas, the time of bud-burst and other growth stages are important for growers because it is considered that the highest quality grapes are obtained from the earliest ripening fruit (Wilkinson, 2001).

Three field trials that have monitored frost risk and/or delayed bud burst of grapevines have found varying results. Application of composted mulches produced from garden organics did not observe frost risk of 4 yo Shiraz in Victoria (Schefe and Slattery, 2001). The air temperature 200 mm above the soil surface in composted treatment was reported significantly not different (data was not provided). Similarly application of straw, fine composted mulch and composted mulch to the depth of 10 cm did not delay budburst of 20 yo Traminer and 3 and 10 yo Chardonnay varieties in cool humid high rainfall area of Victoria (Wilkinson, 2001).

However, vermicast+sugarcane trash, pasteurised mulch, and composted mulch used as surface mulch to 15 cm depth in temperate climate of Queensland with winter frost periods (Trial 1) caused frost damage to Cabernet variety by late frost in October (Biala, 2001). The frost damage ranged from dieback of new shoots to more or less severe splitting of the lower part of the stem. The most damage occurred for pasteurised mulch (25%) followed by vermicast+sugarcane trash mulch (10%) compared to control. The frost damage of vines under composted mulch was same as that of control (about 13-16%) suggesting that the application of pasteurised mulch increased frost damage by 9-12% over control. Long term and statistical significant data is required to conclude the damage was significant. Thicker mulch application of 15 cm in the Queensland trial as opposed to 10 cm deep in Victorian trial, or different maturity of RO products (pasteurised vs composted mulch), or the different vine varieties (Shiraz vs Cabernet & Chardonnay) or the lateness of the frost in the Queensland trial, combined with the different minimum temperatures at two locations may have contributed to the variation in incidence of frost damage. The effects of varying mulching depths and RO products maturity on various vine varieties under similar winter conditions needs to be evaluated in future investigations.

Frost risk investigations discussed above were not carried out specifically in these trials but was monitored as a side issue. Wilkinson (2001) has reported the colour and composition of composted mulches may not represent the same frost risk as straw mulches used as standard practice. These issues require further and specific investigations including effects of different mulching depths and maturity of mulches on frost risk to assure growers that application of mulches are safe to use in frost prone areas.

3.3.1.4 Conclusions: Reduced risk of crop failure

None of scientific field trials monitored the affects of mulch application on incidence of pest and disease. Few trials studied affects on frost damage in cold climate and crop stress from hot weather.

Based on limited data it suggests that application of mulches to vines has the potential to reduce crop stress in hot climate, and composted mulches appear to pose no frost risk to vines in cool climates.

3.3.2 Increased revenue

The application of mulches can increase the revenue of a viticulture enterprise through increased yield, produce quality and time to market.

3.3.2.1 Fruit yield

Grape yield is determined by the overall growth of grapevine, which is controlled by many factors such as vine variety, environmental conditions and management practices. The components of grapevine that determine its yield are stem diameter, number of shoots and nodes, cane weight, bunch number/vine, bunch number/shoot, bunch weight, berry weight, and berry number/bunch (Coombe and Dry,1992).

The natural state for the grapevine is unpruned and it has an inherent self-regulating mechanism to balance between shoot (vine vigour) and fruit growth with a certain yield. Commercial vine growers commonly apply a range of pruning levels to increase yield by regulating vegetative growth (vine vigour) i.e. adjusting number of shoots and nodes and position of nodes which influences bunch number and size hence fruit production and quality. Pruning is defined as the removal of living shoots, canes, leaves and other vegetative parts of the vine. It has important implications for the vine function as it influences (Coombe and dry, 1992):

- the form and size of the vine,
- the balance between vegetative and fruit growth in the vine, and
- the quantity and quality of fruit production.

Composted mulches produced from garden organics and blend of garden organics and biosolids applied as surface mulches under deciduous fruit trees at Bathurst have found significant increase in lateral shoots and pruning weights (NSW Agriculture, 2000b). Mulched trees extended vegetative growth into autumn therefore did not enter into dormancy, which can be a problem for cooler climates (NSW Agriculture, 2000b). Excessive vegetative growth of fruit crops can reduce crop yield and quality.

Some management practices such as application of excess N than vine's requirement and excess soil moisture enhance vegetative growth. High vigour may lead to a disorder called primary bud-axis necrosis, which results in decreased yield potential (Coombe and Dry, 1992). Increased vigour also incurs extra management expenses in pruning costs, and higher risks of developing foliar diseases (Wilkinson et al., 2000). Excessive growth of vines can lead to increased shading of berries and lower sugar content by reduced photosynthetic activity as well as promote the incidence of diseases (Pinegro Products Pty Ltd, 2000). Application of mulches considering nutritional requirements of vine at various growth stages should not enhance vegetative growth and not have a negative effect on fruit yield and quality.

The studies with RO products across various parts of the world have suggested that crop yields increase with increased RO application but responses were variable (NSW Agriculture, 2002b). Most trials (Twenty trials out of total 27 trials) that measured fruit yield reviewed for this report suggest that grape yield was statistically not different or unaffected in various mulched treatments compared to unmulched treatments [Wilkinson, 2001; Schefe, 2001; Biala, 2001 (Trial 1; Harvest data for Trials 2 & 3 was not available due to bird damage); Paulin, 2001 (Trials 3 & 4 and Trials 6 & 7 were not harvested yet); Wong, 2001 (Trials at Tumbarline, Arrowfield & Orange sites)]. Please note fruit yield for Queensland Trial 1 was measured from the grapes that were thinned out four months before the harvest therefore may not represent true yield.

Western Australian Trials 1 and 5 (Paulin, 2001) that applied composted mulches at 2.5, 5 and 7.5 cm depths and standard straw mulch reported slight increase in crop growth and yield (15-20%). In Trial 1, mulched treatments increased trunk diameter, harvest weight, number of bunches and bunch weight of 4 years old Shiraz established on sandy soils. In this trial (Trial 1), lower mulch rates had higher yield than control. Straw was less effective than composted mulches. In Trial 5, average bunch and berry weight of 2 years old Chardonnay increased (20-40%) with increasing mulch rates (grown on light gravely loam over clay which is considered represent better soil used for grape production in the region). Composted mulches in Trial 5 were again more effective than straw mulch. However in this trial (Trial 5), higher mulch rates had higher yields.

CSIRO Land and Water in South Australia has been conducting field trials with various crops including grapevines (different varieties and ages) using composted mulches as surface mulches at varying depths for last 5 years and have found improved vine growth, increased grape yields with increasing mulch rates (Buckerfield, 1999a & b and 2001b). In some trials the grape yield in mulched treatments has been reported to increase from 100 to 300% due to increase in bunch number and berry weight. The fruit yield data of Cabernet Sauvignon (trial established at MacLaren Vale in 1998) grown on deep sandy soils has been monitored for 4 years and reported significant increases in fruit yield ranging from 25 to 50% resulting from the application of 7.5 and 15 cm deep composted mulches (Buckerfild, 2001b). The yield has increased due to increase in bunch number/vine, bunch weight, berry weight and berry numbers/bunch. In this trial lower mulch rates were more effective than higher rates.

A **demonstration trial** conducted in Victoria have also reported improved vine growth and increased yields in mulched compared to unmulched treatments. Yield increase of 6 yo Shiraz ranged from 10 to 15% (Greenspace Processing and Marketing Systems, 2000).

Application of composted mulches produced from plantation materials and pig manure in another **demonstration trial** in Victoria have recorded about 5% increase in stem diameter of 2 yo Semillon after 20 and 70 months of mulch application (Pingro Products Pty Ltd, 2000). This trial also reported increase in average bunch weight by 17.6% in mulched compared to unmulched treatments and resulted due to increase in number of berries and slightly larger berry size (Pingro Products Pty Ltd, 2000).

Generally it is considered that low fertility soil exhibit better response to the application of RO products. The levels of SOM in the control plots of Victorian and Queensland trials (that reported unaffected fruit yield) ranged from 3 to 5.6% and are considered high (3-5%) to very high (>5%). NSW Agriculture Tullamour trial was established on low SOM soil (SOM on the control plot was 1%) also did not increase fruit yield.

From the data available there does not appear to be any clear pattern to increase yield via mulch application. South Australian and Western Australian trials that have reported slight to significant increases in fruit yield did not provide baseline soil quality data/climatic data. Documentation of soil characteristics and climatic data is important for developing a clearer understanding of the relationship between mulch application and yield. Majority of fruit yield data in these trials was obtained from one season harvest suggesting long term and statistically significant data is required to demonstrate this performance benefit of mulches to grapevines.

The results on grape yield arising as a result of mulch application though have shown fruit yield unaffected in most cases or increased in few field trials. Most important is that none of these field trials reported reduction in grape yield. Maintaining sustained grape yield may be highly desirable for growers so long as grape quality is maintained, and the incidence of pest and disease is not increased.

3.3.2.2 Fruit quality

Although increases in grape yield is a bonus for growers, the fruit quality such as sugar content is more important in the process of wine making. It is considered that significant increases in berry size may affect fruit quality such as flavour, colour, juice to skin ratio, sugar content, etc. therefore yield increases due to significant increase in berry size are not desirable.

The investigations using RO products in agriculture carried out across various parts of the world and reviewed by NSW Agriculture (2002b) have reported positive effects on both plant growth and fruit quality, but results were again variable. The field trials with several crops have shown that the use of RO products resulted fruits with higher levels of desirable ingredients (e.g. vitamin C, trace elements) and lower levels of potentially detrimental components (nitrates) compared to those grown with complex chemical fertilizers (Biala, 2000).

The international literature review on use of compost in viticulture carried out by Biala (2000) has listed some positive effects of using RO products in viticulture on wine quality:

- Grape grown with RO products had wine colour two times intensive compared to conventionally fertilized products, and
- Phenolic substances that are largely responsible for the taste of wine were found higher in wine produced from grapes grown on soil amended with RO products. Note: the RO products used were produced from pomace, which is high in phenolic substances.

Biala (2000) suggests that such phenolic substances are produced during the composting processes of other materials and also responsible for suppression of pathogens. The organic wastes from olive industry contain high concentration of phenolic substances. Composting garden organics with waste products from olive industry could be an option to produce mulches specific for viticulture that could potentially reduce grapevine diseases as well as improve fruit and wine quality.

The international literature review on use of compost in viticulture carried out by Biala (2000) has reported that the reduction in water stress caused by mulch application is indirectly responsible for improving wine quality, because water stress reduces the levels of amino acids in must (grape juice before fermentation), which can lead to fermentation problems and less aroma in the wine.

Traditionally wine industry measures three fruit quality parameters that includes the levels of total soluble solids (or Brix) which is a measure of sugar content, juice pH and juice acidity. There are more important fruit quality parameters that contribute great to fruit quality but are not commonly tested such as colour, tannin, aroma, flavour, and phenolics (pers. comm. with Sally Bell, Viticulturist, The Australian Wine Research Institute).

During discussions with Sally Bell with The Australian Wine Research Institute (AWRI) regarding grape fruit quality she explained that during the ripening of grapes, sugar and juice pH increases while juice acidity decreases. The levels of sugar are important for wine industry because it reflects on alcohol production and other wine properties. Juice pH determines colour stability, microbial activity during fermentation and buffering capacity. Titrable acidity or juice acidity is the indicator of mouthfeel properties. No acid means grapes lack palate.

The Cooperative Research Centre for Viticulture (CRCV) along with wine industry have identified the key indices of wine grape quality. These indices are Brix, pH, flavour, titrable acidity, phenolics, berry size and temperature (http://www.crcv.com.au/research/programs/one/projest1.1.2_update).

Discussions with Leigh Fransis of CRCV revealed that grape vine quality parameters expected by wine producers from growers vary from winemaker to winemaker and among regions. Each large wine producer usually signs a contract with growers of the area for expected fruit quality parameters for the season. Some wine producer accept a range of fruit quality parameters. The levels of sugar are important for wine industry because sugar contents reflect on production, colour and flavour of the wine. For example sugar levels above 15 Baume are not desirable as it affects on wine flavour. Juice pH and acidity are not as critical for wine production and some variations are acceptable to wine industry. The variations in juice pH and acidity can be adjusted during wine production.

The fruit quality requirements also vary for different wine styles. For example production of Spottling wine does not require high sugar content, about 11 Baume is sufficient, however good amount of juice acidity is required (pers. comm. with Michel Meunier, National Wine and Grape Industry Centre, Wagga Wagga). Michel informed sugar levels above 16 Baume leads to production of unbalanced berries due to sugar build up in the berry. With increase in berry size sugar content may decrease, but for red wine varieties it is the skin to flesh ratio that is more important to winemakers. That is why wine industry prefers reasonable berry size with appropriate skin to flesh ratio (pers. comm. with Michel Meunier, National Wine and Grape Industry Centre, Wagga Wagga).

As mentioned in Section 2 that more than 80% of total grape production in NSW is used for wine production. This suggests application of RO products to grapevine should not adversely effect fruity quality parameters that impact on wine production, styles and quality as discussed above.

Seventeen field trials (New South Wales, South Australia, Victoria, Western Australia) out of the total 27 trials conducted in Australia using mulches in viticulture have measured fruit quality parameters such as Brix, juice pH, and juice acidity. These trials have covered different grape varieties of varying ages. All these trials have reported fruit quality unaffected or having not changed significantly by the use of mulches.

The exception being a South Australian trial where 5 years old Shiraz was applied with 1, 5 and 15 cm deep composted mulches, reported decreased brix and juice pH (Buckerfield, 1999b). The fruit quality data was not provided. On the contrary Western Australian Trial 5 (Paulin, 2001), recorded increased total soluble solid levels (25%) for higher mulched rates (7.5 cm deep composted mulch) compared to control (no mulch). The total soluble solids levels did not change at lower mulch rates compared to control. The juice pH and acid levels were also higher by 23 and 34 % for higher mulch rates compared to control.

Long term and statistical significant data is required to claim performance benefits in terms of grape quality from the application of mulches in viticulture. Evaluation of quality should be regionally specific, and focus on the varieties and wine industry quality objectives in that region.

The decrease or increase in sugar contents, juice pH and juice acidity above certain range for a paticular wine style or wine production is undesirable because it affects on quality of grapes and wine. The application of mulches to grapevine having no effect on fruit quality will be acceptable to growers than decrease in fruit quality. Improving fruit quality due to applications of mulches will be a bonus for growers.

Most of the data reviewed on fruit quality has been obtained from one harvest except South Australian trial with Cabernet Sauvignon that has measured fruit quality parameters for four years, and in this trial fruit quality was unaffected (Buckerfield, 2001b). The trials that have measured fruit quality parameters have not always tested all three fruit quality parameters. None of the trials have studied the effects of mulch application in viticulture on fruit quality parameters such as colour, aroma, tannin, flavour, phenolics, or wine quality.

3.3.2.3 Time to market

None of scientific field trials reviewed for this report studied the effects of mulches on growth of vine and maturity time of fruits.

As mentioned in Section 3.3.1.3 that it is believed that the highest quality grapes are obtained from the earliest ripening fruit and if application of mulches fasten growth and maturity of grapevines that would enable growers to reach fruit earlier to market and achieve higher price for their crop.

The growth and maturity time is of interest to growers. If mulch application to grapevine demonstrates faster crop growth and early ripening of fruit, it provides a big incentive to growers to adopt mulch application as a part of farm management practices.

3.3.2.4 Conclusions: Increased revenue

Fruit yield and quality data were based on one harvest in most cases. No trials studied affects of mulches on time of grapevine growth stages and fruit maturity, and wine quality.

The application of surface mulches to the depth of 10 cm had shown no undesirable effects on fruit yield and quality and has the potential to increase fruit yield. Thicker mulches than 10 cm are not effective in increasing fruit production on the contrary may reduce fruit production and quality.

3.3.3 Reduced costs in farm management

The research studying beneficial effects of using RO products in intensive agriculture has consistently found that application of mulches reduces weed growth, increases soil moisture and provides nutrients for plant growth (NSW, 2000). These beneficial effects of mulches to viticulture have the potential to reduce farm production costs by reducing use of irrigation water, application of chemical fertilizers and farm chemicals.

3.3.3.1 Weed suppression

One of the primary reasons for using mulches is their effectiveness at controlling weeds and this practice has been in use even before industrialisation. One of the main reasons for weed suppression is the physical presence of a mulch layer which inhibits germination of weed seeds and germination inhibition increases as the depth of mulch layer increases or the burial depth of weed seeds increases. Other reasons responsible for weed suppression are the action of phytotoxic compounds, higher concentrations of carbon dioxide and temperature resulting from degradation of organic matter present in RO products.

International literature reviewed on beneficial effects of RO products have reported that weed growth can be effectively inhibited by the application of mulches to the soil surface (NSW Agriculture, 2000). This review reported that coarse mulches are usually more effective than fine mulches for weed control and the weed controlling effect of composted mulches usually lasts longer than straw (NSW Agriculture, 2000). This performance benefit has been confirmed/demonstrated in all Australian field trials that have monitored weed suppression arising as a result of mulch application.

The field trials carried out in Victoria, New South Wales and Queensland have studied suppression of weed growth resulting from the application of mulches and found significant reduction in weed growth ranging from 60 to 90% compared to control (no compost) irrespective of vine variety and location. Coarse mulches have been found more effective in weed suppression than fine mulches (Wilkinson, 2001). Vermicast+sugarcane trash and pasteurized mulches more effectively suppressed weeds compared to composted mulches in one trial (Trial 1, Biala, 2001), and weed suppression decreased over time (Trial 2, Biala, 2001). Vermicompost+straw mulch applied at same rate has shown variable results at different sites in NSW trials. Compared to composted mulches, the vermicompost+straw mulch was found less effective at Tumbarline and Arrowfield sites but more effective at Tullamour site (Wong, 2001). Composted mulches suppressed weeds by 100% compared to control in a trial at Orange where herbicide was not applied prior to the application of mulches (Orange trial site, Wong, 2001).

The field trials discussed in above paragraph tested weed suppression arising as a result of application of a range of mulches (such as composted mulches, pasteurised mulches, vermicast, vermicompost, sugarcane trash and straw applied at nearly same rate). However these trials did not study the effects of different mulching depth or rate on weed suppression. The Western Australian, Queensland (Trial 3) and South Australian trials applied treatments with different mulching depth but did not measure weed suppression at all. It should also be mentioned that weed suppression in these trials was measured just one of the parameters and was not the sole purpose of the trial.

Generally it is considered that deeper mulches are more effective in weed suppression as well as reducing water evaporation from the soil surface, but thick mulches has the potential to cause undesirable implications therefore mulching depths should be taken into account when considering application of mulches in viticulture (NSW Agriculture, 2000; Buckerfield, 1999a & b and 2001b; Biala, 2001) and these implications are as follows:

- Decreased fruit yield,
- Decreased earthworm activity,
- Inhibit water penetration after rainfall,
- Provide an ideal microenvironment for diseases,
- Cause water logging of heavy soils with restricted drainage,
- Exceed the nutrient requirement of grapevine,
- Restrict further fertilizer side dressings, and
- Nitrogen may be lost from the soil by denitrification if the soil is too wet beneath the mulch.

Application of deep mulches should take into account above mentioned undesirable effects including the amount of nutrients it contributes to vine. Nutrients added through mulch application should not exceed nutrient requirements of vine that may reduce fruit yield and quality. Selection of optimum mulching depth (and particle size) for maximum weed suppression over time is necessary. It is also important to consider the longevity, or reapplication time of mulches.

The diversity of weed species is also affected by mulch application. A Queensland trial using 12.5 cm deep pasteurised mulches as autumn and winter application found weeds growing in mulched plots consisted almost exclusively of grasses while control harboured a mixture of mono and dicotyledonous weeds (Trial 2, Biala, 2001). Grass infestation in mulched areas was patchy and varied greatly. The effect of mulches on diversity of weed species needs further investigations. This would help growers to control weeds effectively using specific herbicides targetted for specific weed species for example narrow or broad leaved weed species.

The results of these trials demonstrated that mulches suppressed weeds, and that weed suppression decreases over time. This has great implications in reducing herbicide use in viticulture hence reducing production costs of a vineyard to buy these chemicals. An attractive incentive for growers may be the potential to claim a premium price in the market for the produce grown with less chemicals or without chemicals.

The results of these trials did not study the effects of different mulching depths on weed suppression, particularly with regard to performance over multiple growing seasons and this needs further investigation. Future investigations should also include effects of mulches with and without prior application of herbicides, and evaluate optimum time for reapplication of mulches to maintain effective weed suppression.

3.3.3.2 Water usage

Another important reason for using mulches is to reduce water evaporation from soil surface. This has the potential to reduce irrigation water usage for irrigated vines, and to conserve soil moisture under non-irrigated and/or dryland conditions, depending upon soil types and irrigation system.

Water usage can also be reduced if application of RO products increases soil's ability to retain more water (relationship between the soil-water content and soil-matric potential) or in other words increases the amount of soil moisture that is available for extraction by plants known as plant available water (PAW). Literature reviewed on soil carbon sequestration using RO products by NSW Agriculture (2002b) has reported that application of RO products increase soil moisture content (gravimetric or volumetric water content present in the soil). However, whilst the soil moisture content or soil water retention can increase in RO amended soils (i.e. incorporation of soil conditioner), but the soil moisture available for plant use is commonly not measured or in some studies as reported in NSW Agriculture (2002b) literature review report remains unchanged. It is the increase in PAW, which provides opportunity and quantification in reduction in irrigation water requirements. Plant available water is the soil moisture content retained at soil-matric potential between field capacity and permanent wilting point.

The mechanisms involved to increase retention of water in the soil include improved porosity and pore size distribution; an increase in the relative number of storage pores; and the colloidal nature and increased surface area of the RO amended soil (NSW Agriculture, 2002b). These changes in soil physical conditions occur over a significant period of time after incorporation of RO products into the soil (i.e. up to 5-10 years). Realisation of these changes takes particularly long time in the case of mulch applications. Most of trials that have measured soil moisture reported increased soil moisture even in the short term after application of mulches, but none of these trials have evaluated the relationship between increased soil moisture and PAW which is important in terms of the potential for reduced irrigation water usage.

Victoria field trials that monitored soil moisture reported increase in percentage of soil moisture in mulched treatments compared to control. Volumetric soil moisture increased 250-300% for 10 cm deep application of composted mulches (Wilkinson, 2001), and about 125% for composted mulch (depth of mulch was not provided) for a non-irrigated vineyard (Schefe and Slattery, 2001). The information on soil types was not available for these trials.

Application of 15 cm deep composted mulch, pasteurised mulch and vermicast+sugarcane trash on sandy duplex type soils in Queensland increased soil moisture about 30-50% at 0-30 cm, and up to 65% at 30-60 cm soil depths for all mulch treatments compared to control (one off measurement Trial 1, Biala, 2001). In the Queensland Trial 2, the difference in soil moisture percentage was statistically not significant between pasteurised mulches (applied in winter and autumn to 12.5 cm depth on sandy clay loam soils) and control (one off measurement Trial 2, Biala, 2001). Please note soil moisture results in this trial were obtained from one off measurement therefore cannot be used to draw any conclusions.

Significant increases in soil moisture percentage have been measured on clay loam soil in South Australia with application of 15 cm deep composted mulch (after few weeks to 4-5 months of mulch application). Soil moisture increased 300% and 100% at 5 and 10 cm soil depths (Buckerfield, 1999b). Five (5) cm thick mulch application was as effective as 20 cm deep straw. Compared to the control, composted mulches applied at 7.5 and 15 cm depths on deep sandy soils recorded 40-70% higher soil moisture even after 4-5 years of mulch application (Buckerfield, 2001b). Deeper composted mulches were more effective in increasing soil moisture. Another field trial in South Australia had observed reduction in soil moisture retention by 20% for 10 cm deep composted mulch (Buckerfield, 2000a), although no reason has been provided for such result.

In NSW trials, soil moisture characteristics observed during dry spells have suggested that the soil under mulched treatments tended to dry more slowly than the soil in control plots (Tullamour site, Wong, 2001).

Soil texture plays an important role in soil moisture retention. The moisture retention potential of sandy soils is generally considered low compared to clayey soils therefore knowledge of soil texture is crucial for the interpretation of soil moisture results. South Australian trials have demonstrated soil moisture increase on clay loam soils was higher than sandy soils. Many reports did not provide information on soil texture.

The results of field trials that monitored soil moisture have reported that soil moisture has increased as a result of mulch application and deeper mulches were more effective in increasing soil moisture. Deeper mulches can cause adverse effects on fruit yield and quality, therefore optimum mulching depth that provides maximum soil moisture increase (across multiple growing seasons) without causing any deleterious effect on fruit quality and quantity needs to be selected. Increase in soil moisture arising as a result of mulch application have made reseachers to conclude that less water will be required for irrigation hence big savings for growers. However, none of these trials have evaluated if increased soil moisture resulted in reduced irrigation water requirements (under properly managed irrigation systems).

In the case of mulches, most likely reason for increase in soil moisture even short term after application of mulches is the reduction in evaporative losses of water from the soil surface rather than improvement in soil physical conditions (i.e. soil porosity and pore size distribution). Direct communication with a grapevine grower in the Hunter who has applied mulch to vines indicated that mulch being hydrophilic retains some proportion of water from irrigation and/or rainfall and shallow roots of vines grow closer to the surface and may under some conditions penetrate into the mulch layer to absorb moisture. This is consistent with discussions with John Buckerfield who identified that some trial sites evidenced root growth to the surface of the soil where mulch had been applied, leading him to suggest that once mulch was applied, there would be little option for the growers than to maintain a mulch layer. Many grape growers also perceive that use of mulch encourages grapevines to develop surface roots thereby preventing vine to develop deeper roots and consider it an undesirable effect (Agnew and Mundy, 2002).

Agnew and Mundy (2002) have reported similar observations from trials using mulch on grapevine. They disagree with grape growers perception that use of mulch prevent vine from developing deep roots. They have observed (as a side issue) that grapevines with mulch application produced a large number of fine surface roots both in the topsoil and in the mulch. The reasons for increased root activity reported were higher soil moisture, uniform soil temperatures and a supply of nutrients from the mulch. However they consider that these fine surface roots were definitely not part of the structural root system of the plant because during the drought far less surface roots were noticed and plants included in the trial were five years old prior to the application of mulch and were able to rely on their deeper roots for moisture and nutrients during the drought. Therefore Agnew and Mundy (2002) argue that development of surface roots with the use of mulch is not undesirable side effect as perceived by grape growers. They opinioned that grapevine will continue to develop surface roots because it uses far less energy. It is most likely this phenomenon will also be influenced by vine variety, (as root system growth varies for different varieties) and irrigation methods and therefore needs further investigations.

Information on the method of soil moisture measurement and at what soil depths measurements were taken is critical for interpretation of results. It is the increase in PAW that is important in terms irrigation water usage and savings. The relationship between increase in soil water content and plant water available has not been characterised therefore needs to be evaluated in future research programs. This information is critical for accurate interpretation of results in terms of irrigation water savings.

A **demonstration** trial having mulched and unmulched rows did not irrigate mulched row once during 4 months of irrigation monitoring (Green Processing and Marketing Systems, 2000) and considered that with this irrigation scheduling about 20000 litres of water can be saved on one watering of one block of 2500 vines @ 2 lt/hr/vine for 4 hrs. This irrigation water saving equals to <1% assuming total irrigation water requirement of one hectare vineyard is 3-5 ML.

Documentation and quantification of actual irrigation water applied in properly managed irrigation systems based on irrigation scheduling that maintains equivalent soil moisture for mulched and un-mulched treatments will provide actual irrigation water savings. The quantification of potential irrigation water savings is likely to be of key interest to growers in terms of cost-benefit and needs to be investigated. Growers currently have tremendous and increasing pressure to reduce irrigation water as a result of implementation of water reforms in NSW and rapidly increasing costs of irrigation water. With the introduction of water reforms in NSW, growers are increasingly paying for water extraction on volumetric basis.

Irrigation water savings from irrigation water usage of mulched and unmulched treatments in properly managed irrigation systems needs to be quantified. Proper soil moisture retention characteristics for varying mulch rates and soil texture classes over long term are necessary to determine the actual water savings potential in terms of irrigation water.

3.3.3.3 Fertiliser application

It is well known that RO products contain nutrients such as N, P, potassium (K), calcium (Ca) and magnesium (Mg) and micronutrients in higher concentrations than agricultural soils, and when applied to the soil nutrients from RO products are steadily released and become available for plant use over time depending upon the nutrient content and maturity of mulch products and environmental conditions. Therefore RO products can be used to replace chemical fertilisers either fully or partially.

It should be noted that the grapevine has low nutrient requirements. Application of mulches that supply excess nutrients than the requirements of grapevine has the potential to increase vegetative growth that may reduce grape yield and quality in vines under production. The nutrient requirements of grapevines should be taken into account when mulches are used in viticulture (Biala, 2000, NSW Agriculture, 2002b).

Nitrogen, P and K are three major elements that are required in higher amounts for growth of most plants. Nitrogen makes up about 1-2% of the dry matter of grapevines and there are about 2 kg of N/tonne of grapes (Coombe and Dry, 1992). Phosphorus makes about 0.1 to 0.3% of the vine dry matter yield and there is about 0.6 kg P in each tonne of grapes. Potassium makes up a considerable part of the dry weight of the grapevine (up to 3%) and is important component of grape juice (Coombe and Dry, 1992). There are about 5 kg of K in each tonne of grapes (Coombe and Dry, 1992).

When RO products are applied at rates that supply excess N, it may have adverse effects on fruit yield and quality (Biala, 2000). Firstly excess N may have adverse effect on the productivity of grapevines, due to an increase in vine vigour in this instance increased vegetative growth is associated with a corresponding reduction in fruit set and bud fertility (Coombe and Dry, 1992). Secondly, the higher N levels in the soil have the potential to leach from the soil, particularly in sandy soils which have low nutrient holding capacity. Similarly mulches that supply excess K may increase levels of K in the soil, consequently increasing K uptake by vine. High K levels in the grapes can increase juice pH to undesirable levels (pers. comm. Sally Bell, Viticulturist, AWRI) and reduce the quality of red wine (Wilkinson, 2001).

Nutrient requirements of grapevine are mainly determined by the yield and variety and may range as mentioned below (Biala, 2000):

N 35-80 kg/ha

P 10-25 kg/ha

K 70-100 kg/ha

Literature reviewed on use of RO products in viticulture by Biala (2000) has reported most or a high proportion of K, Ca and Mg present in RO products become available for plant use immediately (within short time period) and remaining over 4-5 years (Biala, 2000). About 20% of P in RO products is in the mineral form, which becomes available immediately while the remainder is in the organic form and is available to plants after mineralisation of the RO products (Biala, 2000). Virtually all K applied with RO products can be utilised by plants within short time (Biala, 2000).

The situation with N is different. More than 95% N present in RO products is in organic form which becomes available for plant use after mineralisation. It is considered that about 10-20% organic N mineralises each year over 4-5 years and major part of this becomes available for plant use (Biala, 2000), whist a small proportion is lost through different processes such as volatilisation, leaching, denitrification and temporary loss via immobilisation. Approximate availability of nutrients to plants from composted products based on overseas studies (mainly European) has been provided in Table 3.3.

Table 3.3 Approximate utilisation of nutrients from composted products over time (Source: Biala, 2000).

Nutrient availability	**N (%)**	**P (%)**	**K (%)**
Ist Year	15	40	80
2nd Year	20	40	20
3rd Year	10	20	-
Total over 3-5 years	40-50	100	100

The rate at which RO products are mineralised and nutrients are released depends on the nutrient content and maturity of RO products as well as environmental conditions. The knowledge of nutrient availability from various RO products during the growth of vine and over long time period is important to calculate the RO application rates that would not supply excess nutrients, which may have a negative effect on fruit production and quality, whilst minimising losses to environment.

Two Queensland trials (Trials 1 & 2), out of the total 27 field trials in viticulture reviewed for this report, have measured nutrient releases from application of mulches. The nutrient releases were measured over nine months period after nearly 2 months application of mulches.

The release of plant available nitrates on sandy textured duplex soil types in Trial 1 (treatments were vermicast+sugarcane trash, 15 cm deep pasteurised and composted mulches) from composted mulches was slightly higher, but statistically not significant to that of control. Pasteurised mulches and vermiscast+sugarcane trash did decrease the levels of nitrates in 0-30 and 30-60 cm soil depths compared to control. The changes in C/N ratio ten months after application were negligible between all treatments (C/N ratio varied between 15-17 for all treatments) indicating hardly any mineralisation of mulches had occurred. The levels of available P did not vary between all treatments at 0-30 and 30-60 cm soil depths.

Pasteurised mulches on sandy clay loam textured soils in Trial 2 (treatments were pasteurised mulches applied to 12.5 cm depth in autumn and winter) had lower nitrate levels (at 0-30 cm soil depth) than the control at the beginning. The levels of nitrates declined in all treatments, and there was no treatment difference over time at the top 30 cm soil depth. There was also no difference in available P levels between all treatments. The changes in C/N ratio ten months after application were again negligible among all treatments (C/N ratio varied between 22-26 for all treatments) suggesting hardly any mineralisation of mulches had occurred.

Long term data is required to measure release and availability of nutrient to plants from different maturity products, on different soil types and climatic conditions that would help to calculate RO application rates considering mineralisation of RO product, their availability and vine nutrient requirements. This information is critical to calculate RO product application rates to meet specific vine nutrient requiremnet without affecting grapevine yield and quality and surrounding environment.

3.3.3.4 Conclusions: reduced costs in farm management

The results of Australian trials have demonstrated that mulches significantly reduce growth of weeds, increase soil moisture and have the potential to supply nutrients for the growth of vine.

Deeper mulches are more effective in weed suppression and soil moisture retention but must not exceed nutrient requirements of grapevines.

Selection of optimum mulching depths that provides maximum weed suppression and soil moisture retention over time, without exceeding nutrient requirements of grapevines needs to be identified.

Weed suppressive performance of mulches decreases over time (within 1 year), while soil moisture retaining ability can continue for perhaps 3-5 years therefore reapplication time of mulches should consider these issues for realising maximum benefits.

3.3.4 Increased farm capital value

3.3.4.1 Introduction

Agricultural activities particularly cultivation of soil reduces levels of soil organic matter (SOM). It is estimated that about 80% of Australian soils have lost up to 50% of the total soil organic carbon (SOC) in the top 20 cm of soil profile (Australian Greenhouse Office, 2000). By world standards, Australian soils have low SOC and in 1983 it was estimated that 75% of Australian soils have <1% SOC in their surface horizons (Spain et al., 1983), this situation can only have continued to decline since. For vineyards in Europe, it has been estimated that approximately 4, 6 and 8 t/ha per year of SOM is lost on medium to heavy, light and rocky and steep soils (Biala, 2000).

Soil productivity determines long term production of crops hence reflects on farm capital value. Organic carbon is a significant component of RO products and when added to the soil, over time, will increase SOM and restore and enhance soil health. Soil organic matter is a major determinant of biological, physical and chemical fertility of the soil, and consequently soil productivity (Charman and Roper, 1991).

3.3.4.2 Soil biology

Recycled Organics products are not only a source of nutrients and organic matter, when added to the soil they influence the growth of microorganisms including the size, biodiversity and activity of the microbial population that plays crucial role in soil health and sustainability (NSW Agriculture, 2002b).

Two field trials out of total 27 trials reviewed for this report have studied the effects of RO applications as surface mulches on soil biology. Queensland field trial found total bacterial and fungal biomass at 0-30 cm soil depth was well above the desired range (100-150 & 200-300 $\mu g\ g^{-1}$) for all mulched treatments (pasteurised mulches applied in autumn and winter to 12.5 cm depth) compared to control, while the ratios of active to total biomass for both bacteria and fungi was very low (Trial 2, Biala, 2001). However, it was reported that a herbicide application two days before sampling may have caused detrimental effects on microbial and fungal population of the soil (Trial 2, Biala, 2001).

In another experiment, soil microbial activity was found unaffected at 0-10 cm soil depth by the application of all mulches (composted mulch, vermicompost+straw and straw mulches) compared to control while there was a increasing trend of microbial activity at 0-2.5 cm soil depth (Tullamour site, Wong, 2001). This suggests that microbial activity was restricted to soil surface that came in contact with mulches. Pre-treatment microbial activity was significantly higher in all mulches used in this trial than at 0-10 cm soil depth.

Earthworm activity in the soil is a measure of good soil structure hence soil productivity. Composted mulches applied at various depths (2.5, 5 and 10 cm) increased earthworm activity (Buckerfield, 2001a). The density of earthworm (numbers m^{-1}) increased significantly (4-5 times) in the soil under mulch compared to without mulch (Buckerfield, 2001a).

Application of mulches with higher microbial activity than soil eventually should increase soil microbial activity. Mulches can create environmental conditions that favour increased biological activity.

Long term and statistically significant data is required to demonstrate that application of mulches enhances soil biological activity and soil health.

3.3.4.3 Soil physical properties

Inappropriate soil management practices in tillage based agricultural production systems have adversely effected the soil structure. Soil structure is the architecture of the soil, describing the size, shape and arrangements of soil particles or aggregates and the voids between them (Chan, 2001). Soil physical properties such as soil moisture characteristics and hydraulic properties, bulk density and soil porosity can be linked to one of the most fundamental properties of the soil, soil structure (NSW Agriculture, 2002b). A soil with strong structure that has stable aggregates will exhibit desirable values for bulk density and porosity for a given type of soil that provides adequate soil aeration and available water (NSW Agriculture, 2002b). A well structured soil will also have no surface crusting, infiltration and hydraulic conductivity properties that minimise runoff and retain water for plant use (NSW Agriculture, 2002b). These characteristics define physical environment of the soil ecosystem and are critical for a healthy soil and sustainable agriculture (NSW Agriculture, 2002b).

Benefits of RO products listed in a literature review report on soil carbon sequestration by NSW Agriculture (2002b) explains that the addition of RO products increases organic matter of the soil which in turn improves soil aggregate stability and physical parameters such as bulk density and porosity, water holding capacity and infiltration. The initial effects of RO products applied as surface mulch on the soil properties would primarily be restricted to the soil surface until further decomposition of mulch and natural mixing takes place (NSW Agriculture, 2002b).

The review of international literature (Biala, 2000) on use of compost in viticulture reported that application of RO products made from manure, compoted MSW, garden organics, sewage sludge have all shown positive effects on soil physical properties such as improvement in soil pore volume, proportion of aerating and draining pores, water holding capacity and aggregate stability. A brief description of important soil physical properties is provided below.

Aggregate stability is the stability of soil structural units (aggregates) when immersed in water (Hazelton and Murphy, 1992). Instability may be indicated by slaking or clay dispersion. An improvement in water stability of soil aggregates is linked to improvement in soil structure. Literature review by NSW Agriculture (2002b) on soil carbon sequestration utilising RO products stated that the role of organic matter in aggregate stability is complex, and is associated with the binding properties of persistent humic acids and microbial derived carbohydrates and gums (formed during the decomposition of organic matter) interacting with the mineral fraction of the soil. The improvement in soil aggregate stability as a result of RO addition reflects in improvement in soil porosity and increased water infiltration rates. However the magnitude of change is dependent upon the initial texture of the amended soil (NSW Agriculture, 2002b), the composition of the RO product, and the manner in which the product is applied (i.e surface mulch or incorporation into soil).

Total soil porosity is the total amount of pores present in the soil and is equal to the sum of the pores filled with water and those filled with the air (Hazelton and Murphy, 1992). Most plants cease to grow when the percentage of pores filled with air falls below 10% (Hazelton and Murphy, 1992).

Soil hydraulic conductivity (K) is a measure of the rate at which water moves into (penetration) and through the soil (infiltration/percolation). Hydraulic conductivity is usually measured as saturated hydraulic conductivity (K_{sat}) which measures water penetration into and through the soil and is expressed as millimetres per hour (mm h^{-1}). K_{sat} of > 120 is very high, 20-60 –moderate and <0.5 extremely low (Hazelton and Murphy, 1992).

Soil bulk density is the oven dry weight of soil per unit volume and is expressed as Mg m^{-3} or g cm^{-3}. It is closely linked with porosity and to the ability of plant roots to penetrate the soil profile. The critical values of soil bulk density varies with soil texture however 1.3-1.6 Mg m^{-3} is considered a moderate range (Hazelton and Murphy, 1992).

Soil strength determines the resistance of the soil to failure or shearing (to cut through the soil) (Hazelton and Murphy, 1992). Plant roots often need to cause soil to shear in order to grow. The value of soil strength, which limits root growth depends how the soil strength is measured. The soil strength is very dependent on the moisture content at which it is measured and this needs to be taken into account when interpreting results. The soil strength value of <1 MPa is optimum for root growth and value of 2.4 MPa significantly, restricts the root growth (Hazelton and Murphy, 1992).

Few field trials have studied the effects of mulches on important soil properties such as bulk density, soil hydrology, soil strength and soil temperature.

Application of composted mulch (10 cm deep), vermicast+straw (1+20 cm deep) and straw (20 cm deep) to vinegrapes did not significantly change bulk density of the soil compared to control but have shown a trend to reduce bulk density at 0-5 and 5-10 cm soil depths (Wong, 2001).

Composted mulches applied at various depths (2.5, 5 and 10 cm) reduced soil strength below levels considered critical for root penetration. Soil strength of mulched treatments decreased compared to unmulched treatment from 3.25 to 2.75 MPa (15%) (Buckerfield, 2001b). There is no information available on soil type for this experiment and how soil strength was measured. In another experiment where composted mulch was applied to deep sandy soils at 7.5 and 15 cm depths, soil strength reduced significantly at 50 cm soil depth from control of 2.1 to 1.6-1.8 MPa (23%) for mulched treatments (Buckerfield, 2001b). The water infiltration measured for this experiment increased from control of 5.8 to 11-13.8 mm hr^{-1} for mulched treatments, an increase of 100-150%. Information how water infiltration was measured, at what soil depth and when has not been reported. This information is essential for interpretation of results.

Soil heat flux and soil temperature improvements have been observed beneath the mulched layer compared to that of control (Schefe, 2001). No data has been provided for these measurements. New South Wales trial at Tullamour site measured soil temperature at 5 and 20 cm soil depths for 10 cm deep composted mulch, 1+20 cm deep vermicompost+straw, and 20 cm deep wheaten straw applications. At both depths soil temperature was consitently higher for the control than for all mulched treatments. The fluctuations in soil temperature were less for all mulched treatments compared to the control at both soil depths, though soil temperature fluctuations were more noticeable at the topsoil. Composted mulch treatment had consistently 2-3^{o}C higher temperature compared to both straw mulches.

Application of surface mulches have shown a trend in improving soil physical properties. However, it takes long time (more than a single growing season) to realise changes in soil physical properties arising from the application of mulches, therefore long term and statistically significant data would be required to claim this benefit.

3.3.4.4 Soil chemical properties

As discussed earlier the addition of RO products to the soil has the potential to increase SOM which is largely responsible for much of the soil chemical properties such as pH, cation exchange capacity (CEC), electrical conductivity (EC) and nutrients.

Soil pH – is a measure of acidity or alkalinity, and characterises the chemical environment of the soil. It provides guide to likely deficiencies and/or toxicities and nutrient availability. The ideal pH for plant growth ranges between 5 to 8. Nutrient availability for plant use may be affected, and deficiency or toxicity of elements may happen occur outside this pH range.

Cation exchange capacity (CEC) – is the capacity of the soil to hold and exchange cations. It is a major controlling agent of stability of soil structure, nutrient availability for plant growth, soil pH, and soil's reaction to chemical fertilisers and other soil amendments. Cation exchange capacity is expressed as centimoles of positive charge per kg of soil (cmol(+) kg^{-1}). The CEC of the soil in the range of 12 to 25 is considered moderate for optimum plant growth (Hazelton and Murphy, 1992).

Electrical conductivity (EC) – is a measure of soil salinity which relates to the presence of water soluble salts in soil solution, mainly of chlorides, sulphates, carbonates and nitrates of sodium (Na), Ca, and Mg. Salinity is usually determined by measuring electrical conductivity of soil:water suspension and is expressed as decisiemens per metre (dS m^{-1}). The salinity of saturated extract (EC_e) <2 dS m^{-1} has negligible effects on most crops and EC_e in the range of 4-8 dS m^{-1} affects many crops in terms of reduction in crop yields (Hazelton and Murphy, 1992). The salinity of saturated extract is obtained by multiplying EC of soil:water suspension with soil texture classes. The multipication factor ranges from 6 for heavy clays to 17 for sandy, loamy sand and clayey sand (Hazelton and Murphy, 1992).

Nutrients – As mentioned earlier in the section 3.3.3.3 that RO products, when added to the soil, have the potential to increase nutrient levels of the soil which over time become available for plant use. Therefore RO products can be used to replace chemical fertilisers fully or partially. The main nutrients that are added via RO products, depending upon source and quality of the product, are N, P, K, Ca and Mg.

Five of the field trials (Victoria, Queensland and New South Wales) have measured soil chemical properties associated using RO products as surface mulches.

The soil chemical properties such as pH, organic matter, total carbon, N, P, S, Ca, Mg, Na, sulphur (S), Manganese (Mn), iron (Fe), and boron (B), available P and K, nitrates, CEC and exchangeable cations measured at 0-15 cm soil depth did not change significantly after two applications of straw mulches, fine composted mulch, and coarse composted mulch to the depth of 10 cm (Wilinson, 2001). The exception being the levels of total soil K which increased significantly from control of 56 to 106 and 136.7 mg kg^{-1} (about 100-150%) for composted and fine composted mulches respectively. Similarly the levels of available K in the soil increased significantly from the control. The mulched treatments increased K levels from near deficit (<100 mg kg^{-1}) to near adequate (>150 mg kg^{-1}). Note that soil K levels >250 mg kg^{-1} may cause problem with red wine quality (Wilkinson, 2001). Fine composted mulch was more effective in increasing soil K levels than composted mulch. The chemical quality of mulches used in this field trial has not been provided and the levels of K in the soil in control treatment were not high therefore it is hard to explain the reason for increased soil K levels except that the total amount of potassium added with 10 cm deep mulch was most likely high.

Application of 15 cm deep vermicast+sugarcane trash, pasteurised mulch, composted mulch (Queensland Trial 1) and 12.5 cm deep pasteurised mulch as winter and autumn application (Queensland Trial 2) did not affect most soil chemical properties at 0-30 cm soil depth after 10 months of application. The soil properties measured included pH, EC, SOM, total N, P, K, available P, K and Ca:Mg ratio. The levels of total soil K in both trials increased (100-150%) for composted and pasteurised mulches from the control of 71-81 to 150-160 for pasteurised mulches and 212 mg kg^{-1} for composted mulches. In this instance composted mulches were more effective than pasteurised mulches in increasing soil K levels. The levels of SOM also increased slightly (15-20%) in Trial 2 for pasteurised mulches compared to control. Soil chemical properties (pH, EC, total N) measured at 0-30 cm soil depth in Trial 3 after 16 months application of pasteurised mulches to 5 and 10 cm depths were unaffected. However there was slight increase in the levels of SOM (13%), P (40%) and K (11%) for higher rates of pasteurised mulches. It should be mentioned that all these three Queensland trial sites had high levels of SOM in the soil before application of RO products.

The soil chemical properties and nutrient levels measured at 0-10 cm soil depth after 7 months application of 10 cm deep composted mulch, 1+20 cm deep vermicompost+straw, and 20 cm deep wheaten straw found statistically no different results compared to pre-treatment soil (Wong, 2001). The soil chemical properties measured were EC, pH, SOM, total N, P, K and CEC.

The chemical behaviour of the soil is highly complex. The increase in the level of one element in the soil may decrease the uptake of other element by plants (e.g. Ca & Mg or K & Mg) causing nutrient imbalance and resulting in deterioration of soil conditions and/or crop growth (Biala, 2000). The Victorian and Queensland trials have found significant increase in the levels of soil K (100-150%) as a result of application of composted and pastuerised mulches. The increased levels of soil K resulted in an increase in uptake of K by the vine and a reduction in Mg uptake (Wilkinson, 2001). After two applications of mulches over 2-3 years the levels of K in petioles increased significantly (about 50%) for fine and composted mulches. The levels of K in vine were above adequate level of 1.8-3% in all treatments, including the control. The reduction in Mg uptake was statistically significant in 1999 and was on a trend basis only in 2000 (Wilkinson, 2001). High levels of soil K can cause Mg deficiency though plant Mg levels in all treatments remained in the adequate range (>0.3%).

High levels of K in fruits can reduce fruit and wine quality. In the Victorian trials, the increased levels of K in the soil and vine did not affect fruit yield and quality, nor did soil chemical properties particularly soil Ca:Mg ratio. The levels of K in fruits were not measured. In the Queensland trials also, the fruit yield and soil chemical properties were unaffected due to increased levels K in the soil. Queensland trials did not measure fruit quality and the levels of K in the vine and fruit. This highlights the importance of proper planning of monitoring requirements.

As discussed earlier that all or most of the K added via RO products becomes immediately available for plant use. This has been to some extent demonstrated in Queensland trials. The levels of K in the soil after 10 months application of 12.5 and 15 cm deep composted and pasteurised mulches were increased 100-150% (Trials 1 & 2 Biala, 2001), while soil K levels after 18 months of application of 10 cm deep pasteurised mulches were increased only 11% (Trial 3 Biala, 2001). Time, varying mulching depth (10 vs 15 cm deep) and varying initial qualities in the different composts could all be responsible for different K levels in the soil.

It should also be mentioned here that many crops uptake or utilise K from the soil as “Luxury Consumption”, meaning if large amounts of K are present in the soil, many plants absorb it regardeless of their requirement. This is not the case with other major nutrients such as N and P. Plants absorb these nutrients how much they need them.

There are no limits for K levels in mulches, soil conditioners and vermicast as per AS 4454 (2003). The Victorian report did not provide the chemical quality of composted mulches (Wilkinson, 2001). The levels of K in composted and pasteurised mulches, vermicast and pasteurised soil conditioners ranged from 0.4 to 0.6% w/w in Queensland trials (Trials 1 & 2 Biala, 2001). The soil K levels in control plots in Victorian and Queensland trials were not high however in both cases baseline SOM levels ranged from high to very high. Therefore only explanation could be that large amounts of total K were added via 10, 12.5 and 15 cm deep mulches in these trials. This illustrates the importance of selecting and applying RO products considering nutrient requirements of grapevine, and the availability of nutrients for plant use. It also illustrates the importance of monitoring soil and crop conditions after regular additions of RO products, and the need for knowledge of baseline data of the soil as well as RO products being applied.

The levels of heavy metals particularly Cu and Zn were higher than contaminant Grade A and closer to contaminate Grade C in vermicompost and vermicast used in NSW and Queensland trials. In both trials the levels of Cu and Zn present in soils, vines and fruits were not analysed. Although contaminant Grade C products are permissible for application in agriculture, RO products with higher heavy metal contents than contaminate Grade A should be used with caution in all fruit crops including viticulture. Where RO products with high heavy metal contents are applied to fruit crops, the levels of those metals should be monitored in soils, plants and fruits to ensure their concentrations do not exceed maximum permissible concentration.

Although the improvement in soil conditions is desirable and would eventuate steadily over time, most important for growers is that the application of mulches not cause any undesirable effects on soil conditions. It is noteworthy that all these field trials that measured soil chemical properties did not find any negative effect on soil chemical properties resulting from application of mulches (such as increase in EC or decrease in soil pH). Some results have shown slight improvement in SOM and nutrients measured short time after application of mulches demonstrating positive implications of RO use in viticulture. Long term field trials in Europe have demonstrated significant improvement in SOM and soil chemical properties (NSW Agriculture, 2002b).

The results of the field trials that have measured soil physical, biological and chemical properties have demonstrated the ability of RO products as surface mulches to improve soil strength, bulk density, water infiltration, SOM, and the activities of soil microbes and earthworms.

3.3.4.5 Conclusions: Increased farm capital value

A long time is required to realise many of the beneficial changes in soil properties that can result from the application of mulches, therefore long term data is necessary to demonstrate this performance benefit.

None of the trials to date provide sufficient data upon which to calculate the potential for increased farm capital value.

Section 4 Soil conditioner application in viticulture

4.1 Description of field trials

This section provides information on the performance outcomes of RO products used as soil conditioners in viticulture. Soil conditioner in this context refers to products used to incorporate into the soil. There are other terms used for soil conditioners such as ‘soil amendment’, ‘soil additive’, ‘soil improver’ and other products used to condition the soil, such as lime and gypsum, however this section refers only to either composted or pasteurized soil conditioners as defined in the relevant Australian Standard AS 4454 (2003). Soil conditioners may be either composted or pasteurized soil conditioners. Soil conditioners have not more than 20% by mass of its particles with a maximum size of equal or greater than 16 mm as defined in the Australian Standard for composts, soil conditioners and mulches (AS 4454, 2003).

A total of four field trials have evaluated the application of soil conditioner to viticulture and various information is provided as below:

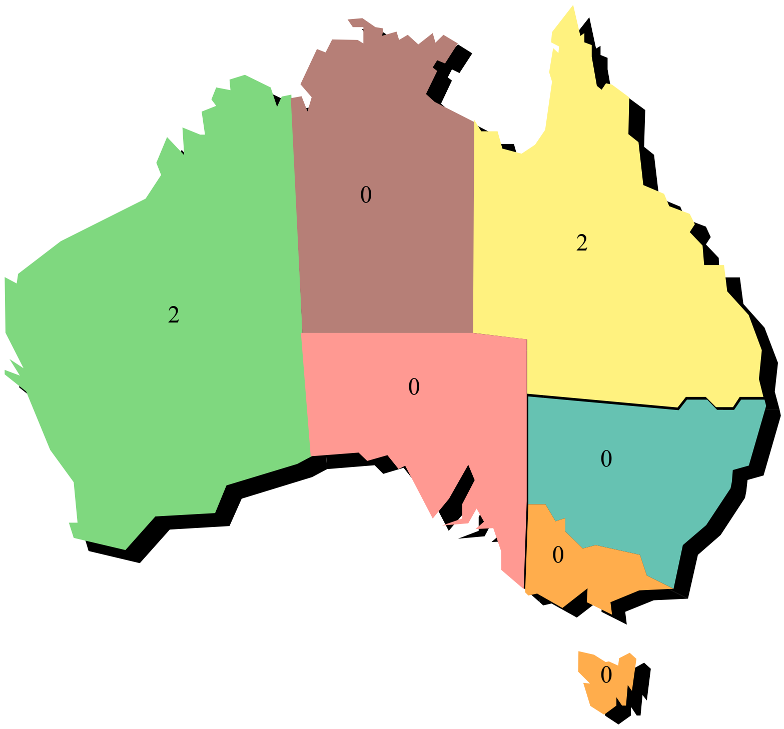
- A detailed description of field trials that studied the performance benefits of RO products used as soil conditioners in viticulture is provided in Appendix 5,
- The scope and location of these trials is detailed in Table 4.1 and Figure 4.1,
- The documented performance outcomes are summarised in Table 4.2, and
- Specific and detailed performance outcomes are documented in Appendix 6.

In Western Australia, two field trials (Trials 2 & 8) were carried out using varying rates of composted soil conditioners at the time of establishing two new vine varieties located at different sites. Besides these trials, two Queensland field trials (Trials 1 & 2) have tested RO products used as surface mulches and soil conditioner (incorporated into soil as a “fertiliser”) for established young vines. Treatments of these trials included a soil conditioner treatment (out of the total 4 or 5 treatments) while remaining treatments applied RO products as surface mulch. The Trial 1 used composted soil conditioner and Trial 2 used pasteurized soil conditioner (see Appendix 1 and 5).

Table 4.1 State-wise summary of field trials conducted across Australia in viticulture using RO products as soil conditioners.

Name of state	Number of trials	Recycled organics products used	Vine varieties tested
Queensland	2	Pasteurised soil conditioners and composted soil conditioners	Cabernet, Flame seedless
Western Australia	2	Composted soil conditioners	Shiraz, Cabernet Sauvignon

Figure 4.1 Number of field trials conducted in viticulture using soil conditioners in various states across Australia.



Like surface mulches, as discussed in the Section 3.1, the performance outcomes of soil conditioners vary and are mainly controlled by factors as mentioned below:

- The RO product quality (chemical, physical and biological characteristics),
- Environmental conditions (temperature, rainfall, soil types), and
- Farm management systems (crop variety and age, RO application method and rate, irrigation/non irrigation, use of fertilisers, herbicides and insecticides)

The information on these factors is therefore necessary to interpret the results of performance benefits of soil conditioners. Next section will discuss information on these factors prevailed in viticulture field trials using soil conditioners across Australia, reviewed for this report.

4.1.1 RO product type and quality

Soil conditioners are used in agriculture mainly to improve soil conditions by adding organic matter and to supply nutrients particularly nitrogen N, P, K, Ca and Mg. Therefore the quality of soil conditioners is important and is mainly determined by the quality of raw materials, compost processing technology and management practices.

The important quality parameters of soil conditioners for use in vineyards are the levels of macro nutrients particularly N, organic matter content, heavy metals, maturity, nitrogen drawdown index (NDI), and impurities (plant propugules, pathogens, stones, glass, plastics, etc.). Chemical and physical characteristics of soil conditioners used in these trials and provided in the reports are presented in Appendix 2.

The quality of composted and pasteurized soil conditioners used in Queensland trials meets the requirements of AS 4454, 2003. The exception was that levels of ammonium plus nitrate (<1 and 1.2 mg L^{-1}) were significantly lower than the required amount of >100 mg L^{-1} for soil conditioners if a contribution to plant nutrition is claimed as per AS 4454, 2003.

Western Australia Trial 2, has tested two soil conditioners named A and B produced from two different sources. Compost B was a vermicast blend. Trial 8 used composted soil conditioners. The quality of soil conditioners used in Western Australian field trials has not been provided. Both trials studied effects of varying rates of soil conditioners applied at the planting time either in hole or trench on the establishment of different vine varieties.

4.1.2 Environmental conditions

The variation in environmental conditions such as climate (rainfall and temperature), soil types and properties will have varying effect of soil conditioners in viticulture. For example the decomposition of soil conditioners in sandy soils is faster than in clayey soils (Chae and Tabatai, 1986), but sandy soils have greater potential to leach nutrients from the soil profile therefore reducing fertiliser efficiency and leaving less nutrients available for plant use than the clayey soils (Maynard, 1999) so the impact of soil conditioner application will therefore vary according to soil types. Unlike mulches, when soil conditioners are incorporated to clayey soils with restricted drainage water infiltration is improved as organic matter added to the soil improves soil structure via reduction in soil bulk density.

No information on climatic conditions has been provided for Western Australian trials and soils of the trial sites were mainly sandy. Queensland trials were located at varying climatic conditions. Trial 1 was located in temperate climate with winter frost periods and Trial 2 had subtropical climate with high summer rainfall. The soils also varied from sandy to sandy clay loam for these two trials.

4.1.3 Agricultural management practices

The vine varieties covered in these experiments included Shiraz, Cabernet Sauvignon and table grapes from 0 years old (new vines) to established vines.

As discussed earlier, the main roles of soil conditioners is to add organic matter to improve soil health and supply plant nutrients, therefore different application rates of the same soil conditioner will add different amounts of organic matter and nutrients to the soil, which will result in variation of performance outcomes. Similarly, different soil conditioners may have significant variation in nutrient content, therefore nutrient budgeting must be considered when applying soil conditioner to ensure the required quantity of nutrients are applied to a crop either from the RO products, or from a combination of RO product and supplementary fertilisers. Higher application rates of soil conditioners, or soil conditioners with high N content may not be suitable for established grapevines because addition of excess N may increase vegetative growth at the expense of fruit production and quality of grapes.

In Western Australian trials, soil conditioners were applied at different rates at the time of vine establishment either in the planting hole or trench and incorporated into the soil. Western Australian Trial 2 applied "composted soil conditioner A" at the rate of 5, 10 and 15 litres and "composted soil conditioner B" at the rate 10 litres per planting hole. Western Australian Trial 8 applied a composted soil conditioner at the rate of 50, 100 and 200 m^3 per hectare in the planting trench.

The composted and pasteurised soil conditioners used in Queensland trials were applied on young established vines. In Queensland Trial 1 composted soil conditioner was applied at the rate of 10 litres per vine which was calculated equal to 57.5 dm t ha^{-1}. In Queensland Trial 2 screened pasteurised soil conditioner was applied at the rate of 10 litres per vine which was equal to 20 dm t ha^{-1}.

The standard farming practices such as fertiliser application may mask the nutrient supply performance of soil conditioners when nutrients added via compost and fertilisers are not matched with crop nutrient requirements because nutrients applied via inorganic fertilisers are more readily available to plants than from RO products particularly, N and P. Plants will absorb those nutrients that are immediately available (i.e from inorganic fertiliers) and therefore may not use nutrients released by soil conditioners. This means applying reduced rate of supplementary fertilisers with RO application, accounting for nutrient content of RO application and also rate of release and availability of nutrients.

The application of soil conditioners under irrigated conditions will have different performance when compared under non-irrigated conditions. Soil conditioners in non-irrigated conditions may improve water retention by the soil after rainfall therefore has the potential to reduce crop stress and increase crop growth and productivity. Under irrigated conditions, application of soil conditioners may reduce irrigation water requirements if increased soil moisture retention result in increased soil moisture available for plant use, however this potential is yet to be quantified.

The standard farming practices including use of insecticides or herbicides were unchanged in most trials. The standard fertiliser practices varied for these trials. The trials were mainly irrigated and the quality of irrigation water has not been provided.

4.1.4 Experimental methodology

All field trials reviewed for soil conditioner section were appropriately designed scientific trials. The experimental design used in Queensland field trials was replicated, randomised block designed while one of the Western Australian trial had Split Plot design. Queensland trials have monitored a large number of performance benefits including frost risk, crop growth, fruit yield, weed suppression, soil moisture retention, nutrient release and soil chemical properties. Western Australia trials have monitored crop growth only.

4.2 Documented performance outcomes

Unlike mulches, when soil conditioners are incorporated or mixed with the soil, they quickly interact with and decompose in the soil, therefore performance benefits of soil conditioners are likely to vary more widely than for mulches. For example mulches are more effective in weed suppression as opposed to soil conditioners. Soil conditioners will improve soil chemical and physical properties comparatively faster than mulches do.

Detailed results of performance outcomes of soil conditioners in viticulture have been provided in Appendix 6 and summary of these results are presented in Table 4.2. Please note, Western Australian Trial 8 was being monitored but no data was available for this trial at the time of writing this report. The results of performance outcomes have been presented under the following four performance categories:

- Reduced risk of crop failure,
- Increased revenue (from increased yield, improved produce quality and time to market),
- Reduced costs in farm maintenance (reduced water usage, fertilizer application, farm chemicals), and
- Increased farm capital value (soil health).

Table 4.2 Performance outcomes of soil conditioners in viticulture.

Trial code and treatments	Reduced risk of crop failure	Increased revenue (yield, time to market, produce quality)	Reduced costs in farm management (water usage, fertiliser application, reduced farm chemicals	Increased farm capital value (soil health)
WA-BP-2001 Trial 2 Split plot trial. Plot A had composted soil conditioners treatments plus 5 cm deep composted mulch as surface mulch. Plot B had similar composted soil conditioner treatments but straw was used as surface mulch. C-Grower practice-Poultry manure CSCA5- Composted soil conditioner A @ 5 lt incorporated within plantation hole CSCA10-Composted soil conditioner A @ 10 lt incorporated within plantation hole CSCA15-Composted soil conditioner A @ 15 lt incorporated within plantation hole CSCB10-Composted soil conditioner B a vermicost blend @ 10 lt incorporated within plantation hole		Vine growth - Percentage stem diameter increased Compost at lower rates increased vine growth compared to higher rates and compost A was more effective than compost B. No. of live vines – lower for composted soil conditioners		
WA-BP-2001 Trial 8 C-Control CSC50-Composted soil conditioner @ 50 m3/ha incorporated into trench centred on the planting line, two days prior to planting CSC100-Composted soil conditioner @ 100 m3/ha incorporated into trench centred on the planting line, two days prior to planting CSC200-Composted soil conditioner @ 200 m3/ha incorporated into trench centred on the planting line, two days prior to planting		No yield or fruit quality measurements were taken yet.		

Table 4.2 Performance outcomes of soil conditioners in viticulture.

Trial code and treatments	Reduced risk of crop failure	Increased revenue (yield, time to market, produce quality)	Reduced costs in farm management (water usage, fertiliser application, reduced farm chemicals	Increased farm capital value (soil health)
QLD-JB-2001 Trial 1 C-control V/ST-vermicast/sugar trash as surface mulch (10 lt/vine) PM- Pasteurised mulch applied to 15 cm depth as surface mulch CM- Composted mulch applied to 15 cm depth as surface mulch CSC- Composted soil conditioners as fertilisers @ 10 lt/vine	Frost damage was caused by late frost in October, 2000. Damage ranged from dieback of new shoots to more or less severe splitting of the lower part of the stem. Composted soil conditioners did not increase frost damage and was same as that of control.	Measurements taken 10 months after mulch/soil conditioner application. Vine vigour - Statistically not different. Grape yield -Statistically not different	Weed growth – Composted soil conditioners did not reduce weed growth. Soil moisture (%) from one off measurement - Increased at 0-30 & 30-60 cm depth. All organic amendments increased soil moisture content 30-50% in the topsoil and up to 65% in the subsoil. Nutrient release - No difference between treatments.	Soil chemical properties - Measurements taken 10 months after mulch/soil conditioner application at 0-30 cm depth. Most properties did not change.
QLD-JB-2001 Trial 2 C-control PMA- Pasteurised mulch autumn application applied at 12.5 cm depth as surface mulch PMW- Pasteurised mulch winter application applied at 12.5 cm depth as surface mulch PSC- Pasteurised soil conditioners as fertiliser @ 10 lt/vine		Measurements taken 10/12 months after mulch/soil conditioner application. Vine vigour - Statistically not different. Grape yield – No yield measurements were available because fruits were damaged by birds.	Weed growth – Composted soil conditioners did not reduce weed growth. Soil moisture (%) one off measurement taken October 2000). Statistically not significant. Nutrient release - Six measurements taken during September 2000 to April 2001. No difference between treatments	Soil chemical properties - Measurements taken 10 months after mulch/soil conditioner application at 0-30 cm depth. Most properties did not change except levels of SOM showed increasing trend for composted soil conditioners. Soil organic matter (%w/w)- Increased by 15-20%.

4.3 Discussion of results

4.3.1 Reduced risk of crop failure

As mentioned in Section 3.3.1 that grape crop can fail due to incidence of pest and diseases, frost damage caused in cool climates and crop stress in hot climates or low rainfall periods and low soil moisture availability in non-irrigated conditions.

Western Australian Trial 2 has not monitored or measured any parameters that reduce risk to crop such as incidence of pest and diseases, frost damage and crop stress. The exception being the number of live vines were recorded which were lower for composted soil conditioners compared to the standard farmer's practice of poultry manure.

Queensland Trial 1 that used composted soil conditioners as fertilisers found that composted soil conditioners did not cause frost damage. The composted soil conditioner treatment had similar frost damage as that of the control.

4.3.1.1 Conclusions: Reduced risk of crop failure

Long term and statistically significant data on incidence of pest and diseases, frost damage and crop stress is required to assess the performance of soil conditioners.

4.3.2 Increased revenue

Viticulture growers can increase the revenue of their farm through increased yield, improved produce quality and time to market as a result of using soil conditioners.

4.3.2.1 Fruit yield

At the time of writing this report, fruit yield data was not available for Western Australia Trial 2. The data on vine growth showed percentage increase in stem diameter, which is an indication of increased yield potential. Lower rates of composted soil conditioners (5 and 10 litres incorporated in the planting hole) resulted in greater increase in vine growth compared to higher rate of 15 lt. Composted soil conditioner A (unspecified) was more effective than composted soil conditioner B (a vermicast blend).

The Queensland Trials 1 & 2 that studied composted and pasteurised soil conditioners found composted soil conditioner treatment had statistically no different fruit yield than the control in Trial 1. Please note fruit yield for Trial 1 was measured from the grapes that were thinned out four months prior to harvest therefore may not provide true indication of yield. The fruit yield data for Trial 2 was not available as birds had damaged the fruits of this trial.

4.3.2.2 Fruit quality

None of the field trials (Western Australia and Queensland) that used soil conditioners measured grape fruit quality.

4.3.2.3 Time to market

No measurements were taken.

4.3.2.4 Conclusions: Increased revenue

Long term and statistically significant data using soil conditioners is required on vine growth stages, maturity, fruit yield, and fruit quality.

4.3.3 Reduced costs in farm maintenance

It is well known that soil conditioners when incorporated into soil improves SOM content of the soil, provides nutrients for plant growth and improves soil moisture retention. These benefits have the potential to reduce vineyard production costs as a result of reduced use of irrigation water, chemical fertilizers and herbicides.

4.3.3.1 Weed suppression

Generally it is considered that soil conditioners do not suppress weeds, unlike mulches.

Western Australian Trial 2 did not monitor the effect of soil conditioners on weed growth.

The percentage weed cover for composted soil conditioner (Queensland Trial 1, 4 months after application) and pasteurised soil conditioner (Queensland Trial 2, 3-5 and 6-7 months after application) was same as that of the control suggesting both soil conditioners did not suppress weed growth.

These results confirm that soil conditioners do not suppress weeds.

4.3.3.2 Water usage

Literature reviewed on soil carbon sequestration using RO products by NSW Agriculture (2002b) has reported increase in soil moisture due to application of RO products. The mechanisms involved include improved porosity and pore size distribution. With an increase in the relative number of storage pores, and the colloidal nature and increased surface area of the RO amended soil, soil water retention is increased (NSW Agriculture, 2002b). Recycled organics amended soils although can increase soil moisture content, but the water available to plants in most studies has not been measured or in some studies have been reported to be unchanged (NSW Agriculture, 2002b).

Western Australian Trial 2 did not monitor the effect of soil conditioners on soil moisture retention.

Queensland Trial 1 found about 50 to 60% increase in soil moisture at 0-30 and 30-60 cm soil depths of duplex type sandy soils for composted soil conditioner compared to the control.

Queensland Trial 2 found statistically not significant increase in soil moisture percentage in the top 30 cm of sandy clay loam soil for pasteurised soil conditioner when compared with control.

Please note the soil moisture results were based on one off measurements and cannot be used to draw any conclusions.

Long term and statistically significant data under properly managed irrigation systems is required for soil conditioners to demonstrate and quantify reduction in use of irrigation water.

4.3.3.3 Fertiliser application

Western Australian Trial 2 did not measure nutrient availability to vines as a result of application of soil conditioners.

The nutrient release was measured for nine months period after 1-2 months application of soil conditioners in Queensland trials. Trial 1 established on sandy duplex type of soils found statistically not significant increases in nitrates and plant available P at 0-30 cm and 30-60 cm soil depths for composted soil conditioner treatment when compared with control, though the nitrates levels were slightly higher in composted soil conditioner treatment than control. The levels of nitrates and available phosphorus were higher in the topsoil than in the subsoil. There was very little difference in C:N ratio between control and soil conditioner treatment suggesting slow mineralisation of added soil conditioner.

Queensland Trial 2 was established on sandy clay loam soil also found no significant differences in plant available nitrates and phosphorus in the top 30 cm soil for pasteurised soil conditioner compared to the control. Indeed the control treatment had higher nitrate levels in the beginning compared to pasteurised soil conditioner treatment. This may be due to temperary immobilisation of soil nitrogen in pasteurised soil conditioner treatment by soil microorganisms decomposing added organic matter, and also indicates slow mineralisation of pasteurised soil conditioners shown by unchanged C:N ratios for all treatments.

4.3.3.4 Conclusions: Reduced costs in farm management

Long term and statistically significant data on water usage and nutrient releases and availability are required to demonstrate and quantify performance benefits.

4.3.4 Increased farm capital value

As discussed in Section 3.3.4 that cultivation of agricultural soil reduces levels of SOM hence soil productivity, crop production and farm value. Incorporation of organic matter via the addition of RO products as soil conditioners to the soil has the potential to increase SOM and improve soil health as determined by biological, physical and chemical properties of the soil. Unlike surface mulches, soil conditioners are likely to improve soil health relatively quickly because soil conditioners are incorporated into the soil. Due to incorporation, soil conditioners, it mineralizes relatively rapidly compared to mulches and the mineralised organic matter directly interacts with soil mineral component leading to improvement in soil structure, the architecture of soil productivity.

4.3.4.1 Soil biological and physical properties

The effects of soil conditioners on the activity of soil microorganisms and physical properties have not been studied in any of these field trials.

4.3.4.2 Soil chemical properties

Western Australian Trial 2 did not measure any of the soil chemical properties discussed in Section 3.3.4.

Queensland Trials 1 & 2 measured soil pH, EC, SOM, total N, P, K, S and Ca:Mg ratio at 0-30 cm soil depth, 10 months after application of composted and pasteurised soil conditioners and did not find any change in soil chemical properties compared to control. The exception being that application of pasteurised soil conditioner slightly increased the levels of SOM and decreased available P compared to control. It is noteworthy that application of composted and pasteurised soil conditioners did not increase the levels of K in the soil unlike treatments with composted and pasteurised mulches in the same experiments (Section 3.3.4.2). This suggests that total amounts of K added through mulches was significantly higher than added via soil conditioners.

4.3.4.3 Conclusions: Increased farm capital value

Long term and statistically significant data on soil biological, physical and chemical properties are required to claim this performance benefit.

Section 5 Gaps and limitations of these studies

The review of project reports on field trials that have used RO products in viticulture across Australia have reported a range of performance benefits to vinegrape production. The short term nature of these studies, due to short term funding, could not confirm and/or study many potential performance benefits of RO products in viticulture identified elsewhere. The gaps and limitations identified from this review are listed below:

1. The main limitation of most studies was that performance benefits were recorded over one season and some reports did not provide statistical analysis of research results, which is not sufficient for a system such as Soil+RO products. Majority of performance benefits in these studies were measured as one of the parameters or as a side issue. Specific investigations targeting specific performance benefits over long term and statistically significant data (over 3-6 years) from such investigations is necessary to demonstrate the performance of RO products in viticulture.

2. A number of trials have neither included adequate characterisation of the composted products applied, nor of cultural practices of the grower and climatic data (i.e. rainfall) for the period of the trial. Whilst such information may be self evident in the local region in which the trial was conducted, this creates significant limitations in terms of identifying trends and outcomes via comparison of different trials, and/or applying performance data beyond the local region. Most of RO products used have been stated were composted but it is not stated to what maturity level and whether maturity levels were characterised.

3. Application of composted mulches and composted soil conditioners has demonstrated significant increases in soil moisture therefore concluded soil moisture increase will reduce irrigation water requirement and save irrigation water. It is the increase in soil moisture that is available for extraction by plants or known as plant available water, which is important in terms of water savings and none of scientific trials have evaluated the relationship between increase in soil moisture content and irrigation water savings. This information is critical for accurate interpretation of results. Quantification of actual irrigation water applied (in properly managed irrigation systems) based on irrigation scheduling that maintains equivalent soil moisture for mulched and un-mulched treatments will provide actual irrigation water savings so that performance outcomes are not simply a result of difference in soil moisture. Most reports did not provide information on the method of soil moisture measurement and what soil depths measurements were taken.

4. Two Queensland field trials studied the release of nutrients after application of mulches and soil conditioners for one season and did not find any change. Recycled organics products release nutrients variably and slowly over 3-5 years after the decomposition of organic matter present in the RO products. Mineralisation of RO products, and release and availability of major nutrients for plant use under Australian environmental conditions are not known and

have not been evaluated in any of these trials. This information is critical for reliable and accurate estimation of nutrient contribution to meet specific crop requirements through RO product applications. Long term data on nutrient release and availability for all three major plant nutrients (N, P and K) is necessary in this regard. Continued and same fertiliser regime to mulched and soil conditioner treatments without regard to the nutrient contribution of the mulch/soil conditioner effectively produces distorted results.

5. Field trials that measured weed growth all demonstrated that mulches significantly reduced weed growth. None of field trials studied the effects of varying mulching depths on weed suppression. A field trial studied the effect of mulch application on weed reduction over time. Weed suppression effect arising as a result of mulch application and without prior herbicide application was studied in only one trial.

6. Disease control is a significant issue for any horticulture crop including grapevines. International literature has reported that RO products in general, and particularly containing phenolic compounds have the potential to suppress soil borne plant diseases and improve fruit and wine quality. None of these field trials studied effects of RO products on incidence of pests and diseases. Demonstration of such performance benefit may provide growers with additional incentive for using RO products in viticulture production.

7. A demonstration trial has observed reduced crop stress and less shrivelled berries for mulched vines in a hot climate. Crop stress leads to loss of production and reduced fruit and wine quality, this has great implications for non-irrigated areas. None of scientific trials studied effects of RO products on crop stress.

8. Vine growers are very careful using mulches in frost prone areas given that mulches may increase frost risk. Two field trials located in two different climatic conditions (Victoria and Queensland) that monitored effects of surface mulches on frost risk have found variable results. Application of 15 cm deep pasteurised mulch (Queensland Trial 1) caused increased frost damage to grapevine, while 15 cm deep composted mulch had similar frost damage as that of control. Composted mulches applied to 10 cm depth in Victorian trial did not cause increased frost damage to grapevine. The effect of variable mulching depths and RO product maturity under similar climatic conditions needs to be tested to resolve and negate this as an issue.

9. The results of field trials reviewed for this report have reported variable results on fruit yield and quality, and most trials have found fruit yield and quality unaffected. Fruit yield and quality data were based on one season measurements after application of RO products in most cases. It has been estimated that at least 3-5 years are needed to demonstrate effects on vine due to application of surface mulches and soil conditioners.

10. It is considered that early ripening fruit produces best quality fruit. None of these trials studied effects of RO applications on grapevine growth stages, fruit maturity and wine quality.

11. Few trials studied the effects on soil biological, physical and chemical properties after application of RO products. These trials have mainly found soil properties unchanged in the short term or in some cases an improving trend in soil chemical and physical properties was noted. Longer time is required for RO products to demonstrate improvement in soil properties, which requires longer term trials.

12. Application of 10 to 15 cm thick mulches significantly increased the levels of K in the soil and its uptake by vine. Resulting fruit yield and quality was found unaffected, but these trials did not study if increased levels of K in vine increased levels of K in fruit, nor its effect on wine quality. Excess of K in grapes is considered has the potential to reduce fruit and wine quality, and as the majority of K in RO products is immediately available for plant use, this issue should be addressed.

13. The levels of Cu and Zn in vermicompost and vermicast used in NSW and Queensland trials were higher than contamination grade A, but within contaminant grade C as per NSW EPA Guidelines for Use and Disposal of Biosolids Products (NSW EPA, 1997). In these trials soils, plants and grapes were not analysed for the levels of Cu and Zn. Although contaminant grade C products are permissible to apply in agricultural production, it would be preferable for the levels of Cu and Zn to be tested in soils, plants and fruits in these trials to identify if higher levels of these heavy metals applied through RO products increased their concentration in soils, plants and fruits over maximum permissible concentration.

Section 6 Conclusions

Field trials conducted across Australia using RO products have demonstrated a range of performance benefits to viticulture. Due to the short term funding of these projects, most performance benefits have been measured over one season whereas benefits from single and repeated applications of mulch are realised over a longer time frame. Many specific performance benefits have been studied in only a small number of field trials and over short term duration, as a result the use of such performance data must be quantified with associated limitations. A number of important performance benefits have not been studied at all in these trials.

This study provides a structure for the consideration of performance benefits which will assist in the design of future trials. These issues are addressed in recommendations in Section 7.2. The provision of this table does not mean that all performance benefits should be studied in a single trial, nor does it mean all performance benefits need to be studied in future trials. However, it is highly recommended that future trials should be designed in a way that specific performance benefit/s is/are studied thoroughly and over the long term to reach conclusive results. Performance benefits that are considered to require attention in the future R & D program are prioritised in Section 7.3 after Table 7.3.

The performance benefits of RO products used as surface mulches and soil conditioners in viticulture from the review of 27 field trials carried out across Australia have been summarised in Table 6.1 and the main performance benefits are discussed below.

Weed suppression

Addition of RO products as surface mulches can reduce the growth of weeds from 60 to 100%. Soil conditioners did not suppress weeds. The weed suppression effect of mulches decreased over time. Pasteurised mulches were more effective in weed suppression than composted mulches (as would be expected due to phytotoxic effects of pasteurised mulches), while composted mulches were more effective than standard practices of straw in many regions. Application of mulches without prior herbicide use had higher relative impact on weed suppression in the short term and thick mulches (>10 cm deep) were more effective in weed suppression. This performance benefit has the potential to reduce vineyard production costs by reducing herbicide use, and therefore provides opportunity for reduced environmental impact and contribution to organic and/or environmental certification.

Soil moisture

Application of RO products as a surface mulch increased soil moisture from 40 to 300%, and the mulching effect to increase soil moisture has been sustained over a long time (up to 4 years), although only one trial of this duration has been implemented. Addition of soil conditioner also increased soil moisture in the range of 50-60% (based on 1 trial and one off measurement only). Thick mulches (>10 cm deep) had greater effect to increase soil moisture. Increased soil moisture does not, however, relate directly to increased plant available water in the soil. It is the increase in soil moisture that is available for plant use or known as plant available water, that directly reduces plant stress and potentially reduces requirement for irrigation. Increase in soil moisture that reduces irrigation water requirements carries great importance for growers in rainfed as well as in irrigated conditions (under properly managed irrigation systems), but this relationship has not been evaluated in any of scientific trials. Soil water is a limiting factor in agricultural production, water deficit can result in increased plant stress, significant reduction in yield or even crop failure. With implementation of the NSW Government's water reforms, growers are under increasing pressure to pay higher water prices based on volume of water extracted for irrigation. If mulch application demonstrates reduced water requirement in irrigated agriculture (under properly managed irrigation systems) and/or moisture conservation in dryland (rainfed) conditions, this can substantially reduce growers water bills and/or reduce risk of crop stress/failure, thereby providing significant incentive for incorporating RO products into farm management practices.

Yield and quality

The use of RO products in viticulture has produced variable results on fruit yield and quality. Most studies have found fruit yield and quality unaffected due to application of mulches and soil conditioners. Few field trials have found a slight increase in fruit yield and quality (ranging from 10-40%). Lower mulching rates (up to 10 cm) and soil conditioner rates (10 litres per vine) did not show any deleterious effects on fruit yield and quality. Whilst the absence of a negative impact on yield and quality is a valuable result, improvements in yield as well as quality will be highly regarded. Yield increases can only be quantified where cultural practices (such as bunch thining) are known and documented. Higher application rates of composted mulches and soil conditioners have shown deleterious effects on yield and quality.

Soil health

Mulching of vines consistently maintained lower soil temperatures and reduced fluctuations in soil temeperatures compared to unmulched vines. This is highly beneficial to reduce crop stress and improve productivity in hot climates.

Few field trials have studied the impact on soil health parameters. These trials have not found significant changes in soil properties over short term resulting from application of RO products. Application of RO products over time will eventually increase SOM, resulting in improved soil properties and soil productivity, and reducing land degradation. However, such performance outcomes have not been demonstrated in short term trials.

Nutrient availability

Two field trials have studied nutrient release from RO products over the short term. Pasteurised mulches were shown to cause a decrease in nitrate levels as expected in the short term. Recycled organics products release nutrients variably and slowly over 3-5 years after the decomposition of organic matter present in the RO products. Information on the release and availability of nutrients from application of RO products in agriculture under different environmental conditions is critical. This data will allow RO product application rate to be calculated considering crop nutrient requirements and environmental conditions without affecting grapevine yield and quality. This information is not known for Australian environmental conditions. Therefore release and availability of major plant nutrients (N, P and K) from RO product applications is highly important in this regard.

Application rate

Application of thick mulches (greater than 10 cm) were more effective in weed suppression and increased soil moisture. However, thick mulch applications or higher application rates of soil conditioners can potentially supply excess nutrients, promoting vegetative growth which can result in reduction in fruit yield and quality, or cause other deleterious effects. Selection of an optimum mulching depth that provides maximum benefit in terms of weed suppression and soil moisture increase without any detrimental impact on crop productivity is necessary. Nutrient budgeting is a necessary consideration when considering product specification and application rates.

Longevity of benefits

Mulches were shown to maintain the effect of soil moisture increase over a long time (3-5 years) while weed suppression effect decreased over time (after 6-12 months) suggesting that reapplication time of mulches should take into account these issues to maximise benefits of mulches to viticulture.

Opportunities for inclusion of RO products in viticulture

Majority of agricultural soils within and around the Sydney basin have inherently low fertility. Decades of intensive cultivation of these soils for agricultural production have further excerbated their poor condition due to continuous decline in SOM causing loss of soil structure, increased surface crusting and hardsetting, reduced water infiltration and increased soil erosion, all of which contribute to a loss of soil productivity. Addition of organic matter via RO products to these soils over time will eventually improve all these soil conditions and help to sustain productivity of land and crops.

The use of RO products as surface mulches has demonstrated significant reduction in weed growth, reduced water evaporation from soil surface, produced more stable soil temperatures, and reduced crop stress. All these performance benefits would assist growers to maintain long term land and crop productivity, whilst potentially reducing irrigation and the use of farm chemicals, hence reducing production costs.

Many performance benefits have not been studied in these trials, and these gaps in research data have been identified and presented in Table 6.1. Other performance benefits have been either studied in only a few trials and over the short term (Table 6.1), or results have not been statistically analysed. Long term and statistically significant data is required to demonstrate and quantify predictable performance benefits that can demonstrate cost-benefit advantage and therefore support increased demand.

Table 6.1 Brief summary of performance outcomes of RO products use in viticulture.

Performance categories	Performance outcomes	RO products as surface mulches	RO products as soil conditioners	Comments
Reduced risk to crop failure	Incidence of pest and diseases	Not investigated.	Not investigated	Specialised mulches e.g. containing phenolic compounds have the potential to suppress diseases.
	Frost risk in cooler climate	Composted mulches did not cause frost damage (3).	Did not cause frost damage (1).	Thick mulch application rates (>10 cm) and pasteurised mulches may increase frost risk.
	Crop stress in hot climate	Potential to reduce crop stress (1).	Not investigated	Crop stress can influence yield, vigour and incidence of pest/disease.
Increased revenue	Fruit yield	Mainly unaffected but lower rates have reported the potential to increase yield (~20).	Mainly unaffected but lower rates have reported the potential to increase yield (1).	Higher mulching depths (> 10 cm) & soil conditioners rates (15 lt/vine) are not effective and beyond a point may cause other negative effects.
	Fruit quality	Mainly unaffected (~17).	Not investigated.	Specialised mulches e.g. containing phenolic compounds have the potential to improve fruit and wine quality.
	Time to market	Not investigated	Not investigated	
Reduced farm management costs	Weed suppression	Confirmed weed suppression from 60-100%. Weed suppression decreases over time (~11).	Do not suppress weeds (~2).	Deeper mulches (15 cm) are more effective in weed suppression but beyond a point have the potential to cause other deleterious effects.
	Reduced irrigation water usage	Confirmed significant increases in soil moisture (40-300%) over long time (3-5 yrs). Increase in plant available soil moisture not investigated (~15).	Increased soil moisture (50-60%). Increase in plant available soil moisture not investigated (2).	Deeper mulches are more effective to increase soil moisture but beyond a point may cause other detrimental effects. No data to support irrigation saving claims.
	Reduced fertiliser application	Short term monitoring suggests slow mineralisation of mulches and hence supply of nutrients (2).	Short term monitoring suggests slight increase in nitrates in the topsoil (2).	Rates of mulches and soil conditioners should not exceed nutrient requirements of grapevine.
Increased farm capital value	Increased soil health (soil biological, physical and chemical properties)	Tendency to increase SOM, reduce bulk density, soil strength over short term. Long term application should eventually improve soil health (~10).	Tendency to increase SOM in short term monitoring (2).	Application of mulches increased K levels (100-150%) in the soil and uptake by plants (50%) that has the potential to reduce grape and wine quality.

Note: the figures in brackets represent the total number of trials that have meseaured/investigated that performance outcome out of total 27 field trials reviewed for this report.

It is reccomended that a comprehensive, multisite, long term strategically designed R & D program be conducted that specifically targets vital performance benefits and covers the crucial gaps identified in Section 5. This program should use RO products of suitable and known specifications, to provide reliable performance data to inform valid cost-benefit analysis. Such a program may be supported by deliberately complementary demonstration trials and other strategies, which may be conducted concurrently on suitable vineyards in the grape production regions. The results of these trials and strategies will assist to inform RO products integration into farm management practices and provide complementary data to accelerate RO product uptake in the viticulture industry.

Section 7 Recommendations

7.1 Product specification for viticulture

Surface mulch is the dominant product relevant for application to established vines as a perennial with established roots. Whilst there may be opportunity to apply composted soil conditioner to vines as a pre-planting soil preparation (Butterfield, 1996), to improve soil structure and water holding capacity, this represents a single application across the life of a vine, whereas mulch applications can be reapplied every 3-5 years.

7.1.1 Mulch products

Based on the results of field trials that have used various RO products in viticulture, a broad product specification of RO products suitable for viticulture has been identified. Compostable organic materials that are pasteurised according to Australian Standard (AS 4454, 2003) pose negligible risk to spread plant pathogens and/or plant propugules (Buckerfield, 1999b). Compostable organic materials that are processed to achieve the maturity levels specified in Australian Standard 4454 for composted products are unlikely to cause the nitrogen draw-down that can be associated with straw, woodchips or paper pulp products. Composted products applied as surface mulches do not seem to pose any problems associated with straw mulches in fire and frost prone areas, if applied at appropriate rates.

Coarser composted mulches and pasteurised mulches were effective in eliminating weeds and conserving water. However pasteurised mulches did not appear to improve crop yields, reduced nitrate levels in the soil (otherwise called nitrogen drawdown) and were reported to cause frost damage in cooler climates. Composted mulches have been recommended in favour of pasteurised products because composted products undergo more extensive composting, have higher amounts of stable humic substances and are less likely to result in N drawdown problems, toxicity or cause frost damage (Wilkinson, 2001).

Elsewhere, a mixture of fine and coarse composted products has been recommended as most appropriate for vineyard application (Buckerfield, 1999b; Wilkinson, 2001) though such treatments have not been studied. Buckerfield (1999b) considers that the fine particle size fraction will be readily incorporated by earthworms in the soil, whilst the coarse fraction will provide protection to the surface. Wilkinson (2001) suggests that fine particles provide a soil conditioning function and the larger particles suppress weeds and ensure the longevity of mulch. This suggestion should be evaluated because no trial has investigated the combined effect of fine and coarse composted mulches.

Many of the significant benefits of a soil conditioner in terms of improved soil structure can take 5-10 years to be realised. It is not clear that the marginally shorter time frame for achieveing potential soil conditioner benefits of including a fine fraction in the mulch is of higher priority than increased longevity of weed suppression and moisture retention offered by the application of a coarse mulch to an increased depth that is possible if fines have been screened out. Whilst some soils, particularly light textured (i.e. sandy) soils may realise particular benefit from including a fine particle fraction in the mulch, it is recommended here that a coarse mulch product is preferable in most instances.

Vinegrapes have relatively low nutrient requirement, which vary at different growth stages and grape varieties. Higher levels of nutrients are required for promoting vegetative growth for the rapid establishment of young vines. However, nutrient requirement is low at the fruit ripening stage. Whilst soil conditioners with high levels of nutrients may be applied at the time of vine establishment, for production vines, composted mulches with lower nutrients are recommended for surface application.

Recycled organics products (i.e composted mulches) containing phenolic compounds have been shown to suppress soil borne plant diseases and also in some instances improve fruit qualities relevant to the production of particular varieties of wine. Waste products from the olive industry or even grape marc contain a high concentration of phenolic compounds, which could be an option to mix these organic agricultural residuals with garden organics to produce disease suppressive RO products.

The following suggestions are provided on the basis of existing data for consideration in developing composted mulch product specification for viticulture applications:

- **Generic mulch product for irrigated vines currently under production**

1. Mature coarse composted mulch with no inherent phytotoxic qualities that has been effectively pasteurised to destroy pathogens and plant propogules.

2. Apply at the maximum depth possible to maximise mulch effectiveness and longevity of moisture retention and weed suppression (thereby maximising avoidance of irrigation and herbicide application) without

    i. causing negative impact on yield or “quality”,

    ii. supplying excess nutrients to vines,

    iii. increasing incidence of pest and/or disease,

    iv. causing anaerobic soil conditions, and

    v. causing increased rate of frost damage.

3. Application rate and nutrient content of the composted mulch should seek to maximise the avoidance or reduction of supplementary fertiliser required.

4. Product specifications should consider application technology and methods, and provide lowest cost per tonne applied (i.e. cost of product plus cost of application).

- **For dryland vineyards**

1. Mulch must not inhibit limited rainfall from reaching the soil (i.e. mulch must not contain significant proportion of fine particles that will absorb moisture. Mulch should be coarse to allow moisture to reach soil).

Whilst these basic performance requirements should be relevant to most vineyards, there are also a range of other performance goals that may demand products that are additional and specifically tailored to the needs of specific regional, varietal and soil requirements to optimise cost benefit advantage to growers, and therefore affordability.

- **Optimum mulch product**

1. The optimum composted mulch product may potentially offer a range of the following performance benefits:

2. Increase yield without negative impact on fruit yield.

3. Increase fruit quality (this is likely to relate to variety specific fruit qualities).

4. Reduce incidence of pest or disease (this may be general or specific suppression; and may be relevant to disease or pest incidence in specific regions and varieties).

5. Support organic or other environmental and/or quality certification for the vineyard or produce.

6. Embody specifications that offer particular benefits to a specific soil type (such as a proportion of fine particles in light soil to improve nutrient and moisture retention) or grower need.

7.1.2 Soil conditioner products

The following suggestions are provided on the basis of existing data for consideration in developing composted soil conditioner product specifications that offer maximum cost-benefit advantage for the establishment of grapevines.

- A mature composted soil conditioner that has been effectively pasteurised to destroy pathogens and plant propogules, and that has no phytotoxic qualities.

- The soil conditioner should offer high absorption/retention qualities, therefore the moisture content and raw materials from which soil conditioner is manufactured should be considered to ensure moisture repellent products are not applied (See Appendix D, AS 4454, 2003).

- The application rate and nutrient content should seek to optimise nutrient provision over time.

- The Goal is to maximise vegetative growth and plant survival/health. Therefore the value of composted soil conditioners that offer increased survival and vigour via suppression of pest and/or disease will be preferred.

7.2 Recommended research and development

Vineyards vary substantially in the quantity and quality of grapes they produce. The grape yield and quality can vary within a block and along rows of a vineyard making it difficult to predict yield and delivery of consistent grape quality.

RO products have the potential to provide vine growers with opportunities for management of vine growth and quality by reducing the use of farm chemicals and avoiding fluctuating soil moisture and temperature conditions, and in improving soil properties over longer term. Differences in environmental conditions (soil types and climatic conditions), RO product type and quality, and farm management practices influence the specific performance of RO products in viticulture applications.

The results of research carried out so far in Australia across various states using RO products in viticulture have demonstrated a range of performance benefits of RO products to vine growers, in particular weed suppression and soil moisture increase. Increased utilisation of RO products in viticulture requires documentation of quantitative costs and benefits of RO products over time. Short term funding of past research has been incompatible with the monitoring of several important performance parameters and monitoring over a sufficiently long duration. On the basis of previous field trials and identified gaps in knowledge, recommended experimental design and monitoring parameters are provided below to guide future research in this area.

7.2.1 Recommended methodology for scientific field trials in viticulture

Field trials should be conducted in prominent vine growing regions and should focus on trial contents most likely to increase RO product use:

- Dominant regional climatic conditions
- Dominant regional soil types (under viticulture production), particularly heavy and light textured soils
- Specific regional area or area of the vineyard that shows maximum beneficial response
- Dominant grape varieties grown in the region
- Grape varieties most likely to evidence beneficial response
- Irrigated and non irrigated conditions

- RO products of relevant and known specification and appropriate nutrient levels
- Application rates that maximise benefits whilst minimising risk and consider nutrient budgeting.

7.2.1.1 Initial site and soil assessment

The research trials involving soil+RO products should begin with an initial site assessment and soil survey to provide baseline information about the site and soils. The baseline information is crucial to monitor, compare and quantify the various performance benefits of RO products within a context that gives the meaningful results.

The site selected for the trial should be assessed for previous and current farming practices, landform and topography. Selection of specific area for the trial should consider dominant soils and varieties in the region that are likely to evidence a beneficial response so as to maximise broad regional relevance/ value of the findings.

7.2.1.2 Chemical and physical characteristics of recycled organics products

Baseline type and quality of RO products is equally important to interpret the results of investigations using RO products in viticulture. It is highly desirable to have knowledge of raw materials used for producing RO products. Composite samples of RO products intended for use in trials should be collected before their application and analysed for parameters outlined in AS 4454 (Standard Australia, 2003), particularly particle size grading, pH, EC, organic matter, moisture content, toxicity, total and available nutrients (N, P, K, B). Selection of parameters for compost analyses will depend on the objectives of the trial. For example analyses of compost for microbial acitivity will most likely be required if impact of compost application on soil microbial activity is being investigated in the study.

7.2.1.3 Experimental design

Given that performance of RO products in agricultural production systems is influenced by numerous factors, it is essential that any R & D program should be based on appropriate methodology i.e. scientifically based experimental design and monitoring requirements. This will allow the results of the R & D program to provide valid quantitative and qualitative data that can be interpreted with due consideration of the effects of environmental conditions when claiming performance benefits of RO application.

Due to unforeseen changes in climatic conditions within a single growing season, across growing seasons and varying soil conditions, agricultural trials should be designed in a way that variation in climatic conditions could be taken into account in the interpretation of results. Any experimental design for a scientific trial should therefore have replicated and randomised treatments. The type of experimental design should incorporate relevant control treatments for comparison. The type of experimental design, number of replications and plan of statistical analysis should be best determined with advice from a biometrician.

7.2.1.4 Product specification and application rates

From 3-5 years experience with application of RO products in horticulture, Buckerfield (2001b) has suggested that 5-10 cm mulch layer will continue to provide significant benefit to vineyard soils without reapplication for at least 3-5 years. Wilkinson (2001) recommends mulch application at 7.5 cm depth in a 0.5 bandwidth undervine once every 3-5 years. Communication with the authors has identified that the commonly accepted figure of 7.5 cm is based on perception of affordability rather than optimising extent of performance benefits. However affordability is a factor of product cost, application cost, performance benefits, and longevity/duration of performance benefit. Therefore increased costs of increased application rate must be balanced against improved performance longevity.

The results of research with RO products have shown that mulching depths of greater than 10 cm though are more effective in weed suppression and reducing evaporation of water from the soil surface, but can have the potential to have other undesirable effects (depending on particle size) as discussed earlier. Therefore the following combination of treatments are proposed, and it is highly recommended to seek advice from a professional biometrician regarding trial design and layout prior to establishment of trials. This is important to plan for the type of statistical analysis that will be applied to field trial results. The combination of the following treatments as presented in Table 7.1 is proposed for future investigations.

Table 7.1. Proposed treatments for future investigations.

Treatments	For establishing vines	For established vines (currently under production)
2 or 3 physiologically different vine varieties	√	√
Different rates of RO products	Three rates of soil conditioners applied at the time of planting: 1. 1st rate - calculated based on tree's nutrient requirements and taking into account mineralisation of organic matter in RO products and availability of nutrients for plant use; 2. Half application rate of treatment 1; 3. Two times application rate of treatment 1; 4. Control with no soil conditioner. Treatments above should be assessed with the addition of 10 cm mulch, and with no mulch.	Three mulching rates –7.5, 10 and 15 cm depths applied in late autumn/early winter, plus control treatment with no mulch. • Annual supplementary application of fertiliser to maintain equivalence in terms of nutrient availability to control • Where nutrients are not varied, compost products of varying nutrient content such as different application rates should apply equivalent total nutrients (each year) • Particle size, maturity and toxicity should be equivalent
Width of mulch in a row	Total 0.5 and 0.75 m	Total 0.5 and 0.75 m
Herbicide and non herbicide	√	√
Irrigated and non irrigated situations (where irrigated-schedule irrigation to maintain equivalent soil moisture for all treatments)	√	√
Bunch thining and without bunch thining	√	√
Control (managed as per "normal" management practices)	√	√

7.2.2 Monitoring requirements and plan of analyses

Long term and appropriate observation, measurements and analyses are essential for the success of a scientific trial in an agricultural production system and statistically significant results of which can be used to claim performance benefits of RO products. The following monitoring program for 5 years after application of soil conditioners and/or surface mulches are proposed (Table 7.2). This program can be amended to suit local conditions, facilities and research objectives. It is not intended to monitor all parameters listed in Table 7.2 in a single trial. Table 7.2 lists all parameters that are most likely to be monitored in a viticulture trial. Researchers should select specific monitoring parameter/s for specifically desgined trial/s. For example a trial designed to study irrigation water savings for a vineyard should monitor/measure soil moisture, air temperature, rainfall and record amount of irrigation applied on each irrigation event, type of composted product used and depth of application in all treatments including control (un-mulched).

Table 7.2. Proposed monitoring requirements and plan of analyses.

Monitoring requirements and frequency	Establishing vines	Established vines
Observation during growth season every year of experimental trial		
Observation of incidence of pests and diseases (weekly)	√	√
Observation of overall crop health (weekly)	√	√
Observing crop stress in hot climates (weekly)	√	√
Observation of frost risk/damage in cool climates (winter time weekly)	√	√
Recording environmental parameters during growth season every year of experimental trial		
Soil moisture (weekly)	√	√
Soil temperature (weekly)	√	√
Amount of irrigation water applied to maintain equivalent soil moisture levels in all treatments (on irrigation event)	√	√
Rainfall and air temperature (after rainfall and weekly)	√	√
Recording weed suppression during growth season every year of experimental trial		
Weed growth and weeds species (initially 2 months after mulch application and thereafter every month until harvest)	√	√
Herbicide application	√	√
Crop monitoring during growth season every year of experimental trial		
Different stages of grapevine growth (growth stages)	√	√
Stem diameter (initial and then every month until harvest)	√	√
Number of shoots, shoot length and number of nodes (during growth stages)	√	√
Pruning weight (after pruning)	√	√
Plant uptake of major nutrients during growth season every year of experimental trial		
Recording fertiliser application/reapplication to maintain nutritional requirements of grapevines for all treatments	√	√
Measurement of N, P and K in leaf petioles during growth season (monthly). Heavy metal levels should be measured in leaves if RO products used had significantly high concentrations of these metals.	√	√
Fruit yield and fruit quality at harvest time every year of experimental trial		
Timing of grape fruit maturity when ready to harvest	√	√
Fruit yield (bunch number/vine, bunch number/shoot, bunch weight, berry number/bunch, berry weight and berry size).	√	√
Nutrient contents in fruits (if required)	√	√
Fruit quality (as relevant: brix, juice pH, juice acidity, colour, aroma, tannin and flavour). Heavy metal levels should be measured if RO products used had significantly high concentrations of these metals.	√	√
Wine quality at the end of harvest every year		
Wine quality (colour, flavour, aroma)	√	√
Soil monitoring during experimental period		
Soil microbial and earthworm activity at two depths (consult soil microbiologist for detailed method/plan)	√	√
Soil bulk density, available water capacity, infiltration and soil structure at the beginning and end of the trial at two depths (0-10 and 10-20 cm)	√	√
Soil chemical properties at two depths (0-10 and 10-20 cm) Soil pH, EC, SOM, CEC, total major elements after 2nd and 5th years of RO products application. Heavy metal levels should be measured if RO products used had significantly high concentrations of these metals.	√	√
Nutrient releases (Nitrates, available P and K) during crop growth at two depths (0-20 and 20-40 cm) every year during trial period.	√	√

7.2.3 Reporting of trial outcomes

Trial reports commonly state that compost was applied. Reports must specify the type of product, its specific characteristics including particle size, maturity and chemical characteristics, application rate and whether the compost product was applied as a surface application, or incorporated into the soil. Reports must specify soil type and environmental conditions. Reports must specify whether compost application treatments have had the same, reduced level or no fertiliser/herbicide applied (to allow comparison with other treatments). Without such information, the reported results are inconclusive.

7.2.4 Demonstration trials

Demonstration trials should ideally be planned and designed after scientific trials where such "trials" are designed to demonstrate specific performance outcomes that have already been proven by scientific trials. Demonstration trials should be conducted on vineyards in prominent vine growing regions.

Vineyards should be selected for demonstration trials on the basis of criteria which seek to maximise uptake of the practice of approprite RO application. Such criteria include consideration of location, soil type, grape variety and climatic conditions that are most relevant to the opportunities for uptake of RO use in the region. The reputation (i.e credibility) and enthusiam of the grower may also need to be taken into account, as these factors can be very relevant to the level of influence that the trial can have on uptake of alternative growing practices in the region.

Demonstration trials may also provide opportunities to work closely with enthusiatic growers to resolve practicalities associated with integration of RO use into existing farm management practices.

7.3 Standard performance categories for designing and assessing research plans

Review of the trial reports and applied experience has led to the development of a number of standard performance categories and monitoring parameters for consideration in recycled organics product application field trials to inform cost-benefit analysis and environmental impacts.

The performance categories presented in Table 7.3 provide a framework for structuring, interpreting and reporting performance data that can speak with meaning to growers. The monitoring parameters within each of these performance categories can provide quantitative and/or qualitative data that will assist to carry out cost-benefit analysis and identification of environmental impacts (whether beneficial or detrimental).

The template provides a guide to help to design and evaluate research plans and proposals by researchers, government and industry. The template provides a structure for reporting that supports comparison and aggregation of data from different trials.

Table 7.3. Standard performance categories and monitoring parameters for consideration in RO product application trials to inform cost benefit analysis and environmental impacts.

Field trial monitoring parameters				
Risk of crop failure	**Increased farm revenue**	**Reduced costs in farm management**	**Increased farm capital value**	**Environmental impacts[2]**
Frost risk • Increased frost risk for surface mulch applications in cooler climates **Crop stress** • Reduced crop stress in hot climate • Variation in crop yield **Crop failure** • Change in germination rate • Incidence of pest and/or diseases • Complete crop failure	**Crop yield (per ha, per input)** • Increased vigour • Increased weight of crop/fruit harvested for sale • Increased number of crop/fruit harvested for sale • Increased size of crop/fruit harvested for sale **Crop quality** • Improved crop/fruit quality parameters specific for each crop/fruit type • Improved crop/fruit quality parameters for storage purposes • Improved crop/fruit quality parameters for processing • Change in heavy metal contents in crop/fruit relative to MPC where low quality (with high heavy metals concentrations e.g. contaminant C grade product) products are applied **Time to market** • Duration to reach first productive cropping • Timelines of maturity (relative to optimum for best price at market) **Ability to continuously grow crops (ability to get crop in)** • Related to soil moisture • Related to soil structure/chemistry*	**Weed suppression** • Reduced number of weeds or weed coverage/time • Reduced specific weed species • Reduced herbicide applications* • Duration of weed suppression benefit **Reduced irrigation water usage** • Increased volumetric soil moisture/time • Increased plant available soil moisture/time[1] • Extent and duration of water efficiency benefit **Reduced fertiliser application** • Contribution to plant nutrients in the soil over time • Reduced application and/or reapplication of fertiliser side dressings* • Nutrient loss due to leaching* • Rate of nutrient releases/time **Reduced other farm management inputs** • Reduced effort/ machinery input/ monitoring or products* **Incidence of pest and diseases** • Reduced incidence of pests • Reduced incidence of soil borne plant diseases • Reduced use of pesticide applications*	**Improved soil biological properties** • Increased total biomass of bacteria, fungus, and actinomycetes • Increased activity of microorganisms • Increased activity of enzymes • Increased earthworm activity **Improved soil chemical properties** • Improved pH & EC • Increased SOM and CEC* • Total and plant available nutrient content • Rate of nutrient releases/time • Increased content of heavy metals in the soil where low quality products are applied (with high concentrations of heavy metals e.g. contaminant C grade product) **Improved soil physical properties** • Improved soil bulk density • Improved soil structure* • Improved water infiltration • Increased plant available water capacity • Reduced susceptibility to erosion*	**Ecological integrity and biodiversity** • Sustained soil health • Reduced water usage leads to increased environmental flows in rivers and improved water quality hence lead to ecological integrity and biodiversity of water resources • Reduced impact on water quality (resulting from reduced erosion and nutrient leaching) **Resource depletion** • Reduced use of agricultural chemicals and fertilisers leads to reduced resource depletion • Reduction in soil structure decline • Reduction in topsoil loss • Reduction in soil organic carbon loss **Global warming** • Reduced use of agricultural chemicals and fertilisers hence reduced production of fertilisers and agricultural chemicals leads to reduced greenhouse gas emissions • Sequestration of carbon in the soil leads to reduced global warming **Soil erosion** • Improvement in soil physical properties leads to reduced soil erosion **Eutrophication** • Slow and sustained release of nutrients leads to reduced nutrient leaching hence reduced eutrophication of water resources

1. Plant available water measurement evaluates potential water savings
2. A number of parameters included in other columns are also applicable here, therefore these parametrs are marked with *

Table 7.3 supports the integration of monitoring parameters with specific trial objectives. The table provides a guide that supports researchers and the relevant industry and/or government client to transparently define objectives, prioritise and plan, cost, and manage research trials. Use of this table allows clients to specify required deliverables, to compare different research trial proposals, to clearly identify whether proposals are relevant to needs/objectives, to have realistic expectations from limited budgets, to share responsibility for outcomes, and to evaluate project delivery. The use of this template is recommended for both industry and government to ensure research plans are transparent and relevant to project objectives. The structure of performance outcomes provided in the table is recommended for reporting of product application trials and for conducting cost-benefit analysis in a manner that is relevant to identifying, aggregating and communicating results from different trials.

7.3.1 Research and development priorities

Table 7.3 is not intended to be absolutely comprehensive, nor to be applied prescriptively. It is not suggested that all parameters are necessarly desirable nor affordable for monitoring in any single trial. It is suggested that future trials should target specific monitoring parameter/s and those parameters be studied in specific trials throughly over a long time (3-6 years). Based on the knowledge gathered from this review, the following monitoring parameters have been identified to be given priority in consideration for future R & D programs:

- Trials should be of relevant duration. Soils, climatic conditions, characteristics of recycled organics products, and farm management practices are known and documented. Recycled organics products selected are of optimum characteristics to maximise agricultural performance and cost-benefit advantage.
- Reduced irrigation water usage - Quantification of increase in soil moisture arising as a result of application of composted mulches and composted soil conditioners and evaluate relationship between increase in soil moisture and irrigation water savings in properly managed irrigation systems.
- Reduced fertiliser application – Quantification of release and availability of major nutrients (N, P and K) for plant use through application of composted mulches and composted soil conditioners over time.
- Duration of weed suppression – Quantification of suppression of weeds over time from different depths of composted mulches.

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Section 9 Glossary

All terms defined in this glossary are based upon definitions given in the Recycled Organics Industry Dictionary and Thesaurus, 2nd Edition (2002) unless otherwise noted.

Term	Definition
Agricultural organics	Any residual organic materials produced as by-products of agricultural and forestry operations, including: weeds (woody and non-woody); animals (processing residuals, stock mortalities, pests), and crop residuals (woody and non-woody), and manures.
Australian Standard	A Standard is a published document, which sets out specifications and procedures designed to ensure that a material, product, method or service is fit for its purpose and consistently performs the way it was intended to.
Bacteria	Microscopic single celled organisms occurring everywhere in nature. Theycan be harmful (cause diseases in plants and animals) and beneficial (decompose organic matter in the soil or compsoting pile or fix nitrogen on legumes from atmosphere).
Biosolids	Organic solids or semi-solids produced by municipal sewage treatment processes. Solids become biosolids when they come out of an anaerobic digester or other treatment process and can be beneficially used. Until such solids are suitable for beneficial use they are defined as waste-water solids. The solids content in biosolids should be equal to or greater than 0.5% weight by volume (w/v). Biosolids are commonly co-composted with garden organics and/or residual wood and timber to produce a range of recycled organics products.
Buffer zone	An area of vegetated land located between development site and a drainage line, creek, river or sensitive area.
Carbon to nitrogen ratio (C:N ratio)	The ratio of the weight of organic carbon (C) to that of total nitrogen (N) in an organic material. Material with a large ratio (20:1) will break down slowly, while a small ratio (8:1) will quickly breakdown. Composted material with high C:N ratio when incorporated into the soil may cause a temporary nitrogen deficiency.
Carbon sequestration	Natural or man-made processes that remove carbon from the atmosphere and store it for extended periods or permanently. A store of sequestered carbon (e.g. forest or soil) is known as a carbon sink.
Cation exchange capacity	The ability of a soil to hold cations, preventing them from being leached. Soils with high clay and organic matter and low sand have high cation exchange capacity.
Clay	Soil particles less than 0.002 mm in diameter.
Compost	An organic product that has undergone controlled aerobic and thermophilic biological transformation to achieve pasteurisation and a specified level of maturity. Compost is suitable for the use as soil conditioner or mulch and can improve soil structure, water retention, aeration, erosion control, and other soil properties.
Compostable organics	Compostable organics is a generic term for all organic materials that are appropriate for collection and use as feedstocks for composting or in related biological treatment systems (e.g. anaerobic digestion). Compostable organics is defined by its material components: residual food organics; garden organics; wood and timber; biosolids, and agricultural organics.
Composted fine mulch	Any pasteurised product which has undergone composting for a period of not less than 6 weeks (excluding polymers which do not degrade such as plastics, rubber and coatings) that is suitable for placing on soil surfaces. Composted fine mulch has not more than 15% by mass of its particles with a maximum size above 15 mm.
Composted mulch	Any pasteurised product which has undergone composting for a period of not less than 6 weeks (excluding polymers which do not degrade such as plastics, rubber and coatings) that is suitable for placing on soil surfaces. Composted mulch has at least 70% by mass of its particles with a maximum size of greater than 15 mm.
Composted products	An organic product that has undergone controlled aerobic and thermophillic biological transfpormation to achieve pasteurization and a specified level of maturity.

Term	Definition
Composted soil conditioners	Any composted product, including vermicast, manure and mushroom substrate, that is suitable for adding to soils. This term also includes ‘soil amendment’, ‘soil additive’, ‘soil improver’ and similar terms, but excludes polymers which do not biodegrade, such as plastics, rubber and coatings. Soil conditioner has not more than 20% by mass of particles with a maximum size above 16 mm.
Composting	The process whereby organic materials are pasteurised and microbially transformed under aerobic and thermophilic conditions for a period not less than 6 weeks. By definition, it is a process that must be carried out under controlled conditions yielding mature products that do not contain any weed seeds or pathogens.
Cover crop	A crop that is grown to reduce soil erosion, conserve nutrients, and provide organic matter. A cover crop may also be grown to nurse or protect another tender species until it is established.
Cultivation	Working the soil with implements in order to prepare it for sowing of crops.
Decomposition	The breakdown of organic waste materials by micro-organisms.
Demonstration trials	Demonstration trials are designed to demonstrate specific performance outcomes that have been proven by scientific trials.
Denitrification	An anaerobic biological process which converts nitrogen compounds to nitrogen gas or nitrous oxide.
Dry matter	The portion of a substance that is not comprised of water. The dry matter content (%) is equal to 100% minus the moisture content (%).
Electrical conductivity	A measure of a solution’s ability to carry an electrical current; varies both with the number and type of ions contained in the solution. Usually measured in deci-Siemens per metre ($dS\ m^{-1}$).
Enterprise	The production of a particular commodity, for example oranges
Erosion	The wearing away of the soil by water or wind. This may be natural or induced by land management practices.
Evapotranspiration	Removal of moisture from soil by evaporation and by transpiration by plants growing in the soil.
Exchangeable cations	Cations that are held by electrical charge to negatively charged clay or humus surfaces in the soil and can be exchanged with other cations in the soil solution.
Extensive agriculture	Refers to the market segment within the recycled organics sector which incorporates: Pasture Farming, Broadacre Farming, and Forestry Farming.
Fallow	A farning practice in which land is left without a crop or weed growth for extended periods to accumulate soil moisture.
Feedstock	Organic materials used for composting or related biological treatment systems. Different feedstocks have different nutrient concentrations, moisture, structure and contamination levels (physical, chemical and biological).
Fertiliser	A substance that is added to the soil to supply essential nutrients for plant growth. Fertilisers may be natural or manufactured.
Field capacity	The amount of water remaining in the soil after free draining due to gravitation. It is the maximum amount of water that a soil can hold under free drainage conditions.
Fine mulch	Any composted and pasteurised organic product (excluding polymers which do not degrade such as plastics, rubber and coatings) that is suitable for placing on soil surfaces. Fine mulch has more than 20% but less than 70% by mass of its particles with a maximum size above 16 mm and complies with the appropriate criteria.
Food organics	The food organics material definition is defined by its component materials, which include: fruit & vegetable material; meat & poultry; fats & oils; seafood (including shellfish, excluding oyster shells); recalcitrants (large bones >15mm diameter, oyster shell, coconut shells); dairy (solid and liquid); bread, pastries & flours (including rice & corn flours); food soiled paper products (hand towels, butter wrap); biodegradables (cutlery, bags, polymers). Such materials may be derived from domestic or commercial and industrial sources. The definition does not include grease trap waste. Food organics is one of the primary components of the compostable organics stream.
Garden organics	The garden organics material definition is defined by its component materials including: Putrescible garden organics (grass clippings); non-woody garden organics; woody garden organics; trees and limbs; stumps and rootballs. Such materials may be derived from domestic, commercial and industrial and commercial and demolition sources. Garden organics is one of the primary components of the compostable organics stream.

Term	Definition
Hard setting soils	A soil that compacts hard when dry. A hard setting soil can lead to erosion.
Heavy metals	A group of metallic elements that include lead, cadmium, zinc, copper, mercury, and nickel. Can be found in considerable concentrations in sewage sludge and several other waste materials. High concentrations in the soil can lead to toxic effects in plants and animals ingesting the plants and soil particles.
Herbicides	Agents used to inhibit plant growth or kill specific plant types.
Humic acids	The chemical or biological compounds composed of dark organic substances that are precipitated upon acidification of a basic extract from soil or compost.
Humus	The dark or black carbon-rich relatively stable residue resulting from the decomposition of organic matter.
Immobilisation, nitrogen Or Nitrogen Drawdown Index or Nitrogen Drawdown	Conversion of nutrient compounds from an inorganic form, available to plants, into the organic tissue of microorganisms (or other plants). The nutrients are unavailable until the microorganisms die and the microbial tissues containing these nutrients decompose. Nitrogen immobilisation occurs when materials with a high C:N ratio are land applied. The microorganisms that use the carbon also assimilate the available nitrogen, rendering it unavailable to plants.
Infiltration	The downward movement of water into soil. It is largely governed by the structural condition of the soil, the nature of the soil surface including presence of vegetation, and the antecedent moisture content of the soil.
Integrated Pest Management	A system of pest control that uses a combination of most appropriate control measures including pesticides, cultural, mechnical and biological means.
Intensive agriculture	Refers to the market segment within the recycled organics sector which incorporates: Nurseries – production, Nurseries – wholesale, Fruit & Orchard Growing, Market Gardening, Mushroom Farming, Turf Grass Growing, and Viticulture.
Land application	The spraying or spreading of solid, semi-solid or liquid organic products onto the land surface, or their injection below the land surface.
Land degradation	The decline in land quality caused by improper use of the land.
Macronutrient or major nutrient	An essential nutrient that is needed in relatively large amounts. For example nitrogen, phosphorus, potassium.
Micronutrients or trace elements	An essential nutrient that is needed in small amounts. Foe example zinc, copper, boron, molybdenum.
Manure	Refers to all faecal and urinary excretion of livestock and poultry that are appropriate for collection and use as feedstock materials for composting or in related biological treatment systems. This material may also contain bedding, spilled feed, water or soil. See also agricultural organics. Such material may be derived from agricultural sources. These materials form one of the material description subcategories within the Agricultural Organics material description.
Market penetration	Strategy for selling existing or conventional products into an existing or established market.
Market segmentation	The process of dividing markets into groups of consumers who are similar to each other, but different to the consumers in other groups.
Maturation	Final stage of composting where temperatures remain steady below 45ºC, and the compost becomes safe to use with plants due to the absence of toxins.
Maturity of compost	Is related to the level of composting feedstock material receives. A mature product is stable and does not cause toxicity to plants. See also Maturation and Stability.
Mineralisation	The breakdown of organic matter into its constituent inorganic components, carried out chiefly by decomposer microorganisms, and, for carbon, during respiration when carbon dioxide is returned to the environment.
Mulch	Any composted and pasteurised product (excluding polymers which do not degrade such as plastics, rubber and coatings) that is suitable for placing on soil surfaces. Mulch can be either composted mulches or pasteurised mulches. Mulch has at least 70% by mass of its particles with a maximum size of equal or greater than 16 mm.
Municipal solid waste	The solid component of the waste stream arising from all sources within a defined geographic area.
Nitrate nitrogen	A negatively charged ion comprised of nitrogen and oxygen (NO_3^-). Nitrate is a water soluble and mobile form of nitrogen. Because of its negative charge, it is not strongly held by soil particles (also negative) and can be leached away.
Nitrification	The biochemical oxidation of ammonia-nitrogen to nitrate.
Nitrogen (N)	Chemical symbol for nitrogen.

Term	Definition
Nitrogen Drawdown Index	A measure of the ability of a composted organic product to supply soils and/or plants with soluble nitrogen. See also immobilisation, nitrogen.
Nutrient availability	The relative proportion of a nutrient in the soil (or compost) that can be absorbed and assimilated by growing plants.
On farming composting	The aerobic conversion of organic materials by microorganisms with technologies based on-farm. By definition, it is a process that must be carried out under controlled conditions yielding cured products. On-farm composting systems are usually outdoors and are based on simple and inexpensive technologies, such as: turned piles, passively aerated or forcedly aerated static piles.
Organic farming	A farming based on the use of natural materials for supplying nutrients and protection to plants and animals. No chemicals such as artificial fertilisers, pesticides or herbicides are allowable for a farm which is certified organic.
Organic matter	Chemical substances of animal or vegetable origin, consisting of hydrocarbons and their derivates.
Pasteurisation	An organic product that has undergone controlled aerobic and thermophilic biological transformation to achieve pasteurisation, but is relatively immature and lacking in stability compared to compost.
Pasteurised fine mulch	Any pasteurised organic product (excluding polymers which do not degrade such as plastics, rubber and coatings) that is suitable for placing on soil surfaces. Pasteurised fine mulch has not more than 15% by mass of its particles with a maximum size above 15 mm.
Pasteurised mulch	Any pasteurised organic product (excluding polymers which do not degrade such as plastics, rubber and coatings) that is suitable for placing on soil surfaces. Mulch has at least 70% by mass of its particles with a maximum size of greater than 15 mm.
Pasteurised products	An organic product that has undergone pasteurisation (a process whereby organic materials are treated to significantly reduce the numbers of plant and animal pathogens and plant propagules) but is relatively immature and lacking stability.
Pasteurised soil conditioner	Any pasteurised organic material that is suitable for adding to soils. This term also includes ‘soil amendment’, ‘soil additive’, ‘soil improver’ and similar terms, but excludes polymers which do not degrade such as plastics, rubber and coatings. Soil conditioner has not more than 15% by mass of particles with a maximum size above 15 mm.
Pathogens	Microorganisms capable of producing disease or infection in plants or animals. Pathogens can be killed by heat produced during thermophilic composting.
Performance data	Quantification of performance benefits. For example quantifying mulching effcets on weed suppression.
Permanent wilting point	The amount of water still held in the soil when plants wilt to the extent that they won’t recover even if water is added. Soils deffer in the amount of water still held at permanent wilting point.
pH	A measure of the concentration of hydrogen ions in a solution. pH is expressed as a negative exponent. Material that has a pH of 8 has ten times fewer hydrogen ions than a material with a pH of 7. The lower the pH, the more hydrogen ions are present, and the more acidic the material is. The higher the pH, the fewer hydrogen ions present, and the more basic it is. A pH of 7 is considered neutral.
Phosphorus (P)	Chemical symbol for phosphorus.
Photosynthesis	The process of plants converting carbon dioxide into carbohydrates by chlorophyll using the energy of sunlight.
Plant avialable nutrient	A nutrient that can be easily taken up by palnts from the soil solution.
Plant available water	Soil moisture that can be used by plants and is held between field capacity and permanent wilting point.
Plant propagule	Plant or part of a plant that could generate a new plant, e.g. a seed, part of a rhizome, corm, bulb, etc.
Potassium (K)	Chemical symbol for potassium
Potting mix	A growing medium suitable for the establishment and development of a wide range of plants in containers.
Processing	Subjecting a substance to a physical, chemical or biological treatment or a combination of treatments. Composting, for example, is a form of processing.
Product development	Strategy for selling new or non-conventional products into an existing or established market.

Term	Definition
Pruning	Removal of plant parts to keep a better form or to control the direction and amount of growth.
Recycled Organics	The term Recycled Organics has been adopted by NSW Waste Boards and EcoRecycle Victoria as a generic term for a range of products manufactured from compostable organic materials (garden organics, food organics, residual wood and timber, biosolids and agricultural organics).
Recycled Organics Industry	A range of related business enterprises involved in the processing of compostable organics into a range of recycled organics products, and the development, assessment, marketing, promotion, distribution and application of those products.
Runoff	Rainfall that is not immediately absorbed into the soil. Water flows across the soil surface and depending on the soil condition the runoff may pick up soil particles and cause erosion.
Saturated Extract	A solution derived by saturating a soil sample with water under standard conditions for a period long enough to dissolve any salts present.
Scientific trials	Scientific trials are conducted to test the performance of particular treatments such as products, latest technologies and practices over existing or standard approaches to statistically demonstrate whether the treatment produced a significant affect or not. An experimental design of a scientific trial should be uniform, replicated, randomized and have a control for comparison.
Screening	The process of passing compost through a screen or sieve to remove large organic or inorganic materials and improve the consistency and quality of the end-product.
Selective herbicide	A herbicide that kill only certain groups of plants. For example 2, 4-D kills broadleaf plants, but not grasses.
Slaking	Breakdown of soil aggregates in water into smaller groups, or micro-aggregates.
Soil aggregate	Groups of soil particles clumped together to form the structure of the soil.
Soil buffering capacity	The ability of a soil to withstand changes in pH. Soils with high levels of clay or organic matter have high buffering capacity.
Soil conditioners	Any composted or pasteurised organic product, including vermicast, manure and mushroom substrate that is suitable for adding to soils (excluding plymers which do not biodegrade, such as plastics, rubber and coatings. Soil conditioners any be either composted soil conditioners or pasteurised soil conditioners. Soil conditioners has not more than 20% by mass of particles with a maximum size above 16 mm and complies with appropriate criteria.
Soil degradation	Soil in which the structure has been damaged, compaction or erosion has occurred. It may also refer to soil acidity and salinity and the loss of nutrients from a soil.
Soil profile	Description of each of the layers (soil horizones) in the soil. Examination of the profile is made to detremine depth, drainage, texture, structure and classification of the soil.
Soil structure	The combination or arrangement of primary soil particles into secondary particles, unit, or peds. Compost helps bind primary soil particles to improve the structure of soil.
Soil texture	A characterisation of soil type, based on the relative proportions of sand, silt, and clay in a particular soil.
Soil type	A general term used to describe the features of particular soils in terms of fertility, colour, texture and parent material.
Stability of compost	The rate of change or decomposition of compost. Usually stability refers to the lack of change or resistance to change. A stable compost continues to decompose at a very slow rate and has a low oxygen demand. See also maturation.
Subsoil	Soil in the lower horizons of the soil profile. The nature and depth of the subsoil is important for drainage and the growth of deep-growing plant roots.
Sustainability	In agriculture, sustainable practices are those which are, and will continue to be, profitable for farmers, that will conserve soil, vegetation and water resources and protect the environment, and that will assure adequate and safe food supplies into the future.
Temperate	Plant species that grow best in cool climates, or during the cooler months of the year; (as opposed to tropical plants, which grow in warmer climates).
Topography	The shape of the ground surface, such as hills, mountains, or plains. It also referes to the slope of the land.

Term	Definition
Topsoil	The top part of the soil profile that contains the most fertile portion of the soil. It is usually darker than the subsoil, because it contains most organic matter. The topsoil is the most important part of the soil for agriculture, and must be protected by wise management. Original surface layer of soil from grassland, bushland or cultivated land.
Toxicity	The potential or ability of a material to cause adverse affects in an organism.
Vermicast	Solid organic material resulting from the biological transformation of compostable organic materials in a controlled vermiculture process.
Vermiculture	System of stabilising organic materials under controlled conditions by specific worm species and microorganisms under mesophilic temperatures. Commercial vermiculture systems include: windrows or beds; stackable trays; batch-flow containers, and continuous flow containers.
Viticulture	Viticulture is the term used to describe grape growing for production of various products mainly for wine, dry grapes, fresh consumption (table fruits), juice for non-alcoholic consumption and concentrated juice.
Water Holding Capacity	The amount of water held in a soil after any excess has drained away following saturation, expressed as a percentage of the oven-dry weight of the soil.
Waterlogged	The condition of a soil, which is saturated with water and in which most or all of the soil air has been replaced. The condition, which is detrimental to most plant growth, may be caused by excessive rainfall, irrigation or seepage, and is exacerbated by inadequate site an/or internal drainage.
Weeds	A plant growing where it is not wanted.
Whole farm planning	A process that assists landholders to analyse the farm operation from the ecological, economic and social perspectives, and social perspectives, and integrates these in redesigning farm layout and management in order to ensure more sustainable production.
Wood and timber	The material description, Wood and Timber is defined by its component materials, which include any contaminated or uncontaminated, treated or untreated, solid or composite wood material that include: off-cuts; crates; pallets and packaging; saw dust, and timber shavings. Such materials may be derived from domestic, agricultural, commercial and industrial, and construction and demolition sources. These materials may be contaminated with paint, laminate and fasteners. See treated timber. Wood and Timber is one of the primary components of the compostable organics stream.

Appendices

Appendix 1: Detailed description of field trials using recycled organics products as surface mulches in viticulture

Appendix 2: Quality of recycled organics products used in viticulture field trials

Appendix 3:Conversion of mulching depth and width to volume of mulch applied per hectare

Appendix 4: Detailed performance outcomes of recycled organics products used as surface mulches in viticulture

Appendix 5: Detailed description of field trials using recycled organics products as soil conditioners in viticulture

Appendix 6: Detailed performance outcomes of recycled organics products used as soil conditioners in viticulture