**Summary report**

Review of past recycled organic field trials in Victoria (1995–2013)



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# Executive Summary

### Benefits of recycled organic products

Within each of the key farming markets that were investigated (market gardening, broadacre cropping, viticulture, orchards, pasture), at least one trial demonstrated either higher crop yields or better quality or both however most trials demonstrated no yield increases. Market garden trials often showed yield losses rather than gains or a neutral effect on yield, commonly attributed to low product nitrogen.

It is generally accepted that higher soil carbon levels provide multiple, long lasting benefits to structure (water infiltration, aeration), chemistry (nutrient retention, resistance to acidification) and biology (structure, nutrient turnover and potential disease suppression), which is why it is considered the key to sustainable soil productivity. Several researchers identified improvements to soil structure, chemistry and/or biology, sometimes substantial.

The findings from trials within one market segment may support findings within another and suggest that, while the benefits from recycled organic (RO) products depend on the product’s physical and chemical characteristics, the method of application, i.e., surface or incorporated plays an important role too.

More specifically several trials involving perennial horticulture (vineyards, orchards, and berry crops) have established that greater soil moisture retention (reduced evaporation) is the main benefit to plant growth and yield from surface applied mulches (Buckerfield 2001, Wilkinson et al. 2000, Clark & Moore 1991). Trials involving broadacre crops have also shown that surface-spread soil conditioners can increase crop establishment, attributed to reduced evaporation (Armstrong et al. 2007b).

### Economics of recycled organic products

Few RO product trials were designed to assess economic benefits, especially savings on variable costs (ground preparation, fertiliser, pest, disease and weed control and irrigation). Instead, estimates of variable costs rely upon feedback from farmers and estimates by researchers. Trials commonly focus on trying to correlate plant growth, yield or quality effects with one or more potential effects on soil, caused by application of an RO product. The effects of affordable application rates were not the focus of the majority of trials.

Cost benefit analyses for farming enterprises are commonly based on gross margins analyses, but for RO products, more accurate analyses would make an allowance for long term benefits. Several researchers have discussed this issue (including Norton 2000, Buckerfield 2001). Unfortunately, long term data is not available, so they are either excluded or assumptions are made regarding the longevity of benefits. For example, surface applied mulches within perennial horticulture (vineyards, orchards) are commonly assumed to have an effective life of three years. However, soil conditioning effects may last longer than this.

Farmers will in all likelihood continue with standard management inputs (poultry litter, herbicide, etc.), as an insurance, even when the use of RO products may demonstrate the opportunity to reduce inputs, because inputs are cheap, and outcomes known in comparison to the potential uncertainties and/or revenue loss associated with declines in yield or quality.

### Trial collation and conducting future trials

A number of treatment effects have not been statistically significant, which can be attributed in many cases to inadequate trial design (sampling intensity, low application rates), and selection of trial sites that may be unresponsive (there may be some growth limiting factor or alternatively, the farmer may have over fertilised, swamping any potential treatment effects).

A better understanding of the decision making processes of producers in each market should inform future trial objectives. Aligning trial objectives with customer expectations and delivering methodical, structured trials will only increase replicability and improve product feedback. Improved product feedback will drive up the standard and quality of product development. The market requires assurance when it comes to the application of RO compost products and some predictability in the anticipated results.

Due to the small trial samples across segments and varying objectives, inputs and measures it has been impossible to provide the comprehensive repository of past field trials that SV had intended. What has become clear through this work is the need for a standard approach to the design, implementation, measurement and reporting of field trials, either scientific or demonstration trials to build the knowledge, expertise and acceptance of RO products. A standardised approach to conducting field trials, targeting issues of significance in each market will enable the easy replication and validation of outcomes and could provide consistently comparative results to support the further development of new products and specifications for RO products. To assist this SV has developed a *Guide: Conducting compost demonstration trials in agriculture/horticulture* to provide compost producers, sellers and end users with considerations when developing on-farm demonstration trials in agriculture/horticulture for compost products. With clear quality standards applied and consistent product delivery, the RO compost industry could mature into a market driven industry servicing the needs and delivering outcomes for Victoria’s significant agricultural sector.

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# Introduction

In 2013, Sustainability Victoria commissioned research to evaluate all known recycled organics field trials in Victoria with the aim of building a defendable evidence base. The research evaluated published and unpublished field trial reports and research papers spanning 1995-2013 with a focus on field trials undertaken in Victoria. The research analysed past field trials with respect to product performance (effects on plant growth, yield, quality and survival and effects on soil physics, chemistry and biology) and the influence of trial design (rigour and robustness) on the ability to measure significant treatment effects. This report provides a summary of the research commissioned.

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# Research overview

There are five key markets for recycled organic (RO) products; intensive agriculture, extensive agriculture, urban and amenity, enviro-remediation and rehabilitation, each with a number of submarkets (ROU, 2007). Both extensive (broadacre cropping and pastures) and intensive agriculture (vineyards, orchards and market gardens) have the potential to use significant quantities of RO products. Sustainability Victoria (SV) has identified that a clear articulation of the potential value that RO products offer to the farmer remains a barrier to market expansion.

Conducting field trials of RO products is an important component in improving the understanding of the benefits of using RO products and to expand market penetration. On-farm field trials serve to prove new outcomes, validate previously demonstrated results and/or encourage growers to take up alternative crop management practices.

A well designed agricultural research trial aims to isolate and quantify treatment effects of an amendment on soil, and hence to plant growth or yield. For RO products, this is particularly challenging because several effects occur simultaneously and they are co-dependent. For example, mulching can increase soil moisture as well as lower soil temperature within the (nutrient rich) topsoil. This provides a more favourable environment for surface (feeder) roots, which allows greater plant uptake of nutrients. RO products may also make a direct contribution to the soil nutrient bank. Further, the activity of soil microbes and macro fauna (earthworms) may also be increased by higher soil moisture and the RO product being a food source, which may increase plant nutrient availability (or decrease it as demonstrated in many trials within market gardening). Despite the challenges, some trials have attributed crop yield to specific soil health improvements (better structure).

### Sources of field trail data

A large number of both scientific (replicated) and demonstration (non-replicated) field trials have been undertaken by farming communities and associations, the compost industry, individual compost producers and several government organisations, including SV, the Department of Economic Development, Jobs, Transport and Resources (formerly the Department of Primary Industries) and the waste and resource recovery groups.

The main information presented in this report was sourced from research journals and government reports with additional sources including agricultural books, personal communication (government researchers, agricultural consultants and farmers) and websites hosted by compost industry associations (Compost Victoria, Australian Organic Recycling Association) and the Recycled Organics Unit (ROU). Data from many industry composters was not forthcoming despite numerous attempts.

Almost all scientific trials involved a state department, university or the Commonwealth Scientific and Industrial Research Organisation (CSIRO). Exceptions were those sponsored by Landcare Australia or a similar land stewardship organisation, which were often conducted by private consultants. Projects commissioned and conducted by private companies may be well-run, but the independence can be questionable.

Table 1 presents a list of the main researchers who conducted many of the scientific RO field trials, and the markets covered by the research. Their reports and papers cover the main trials upon which many of the findings are based. It should be noted that many other important interstate reports were consulted, particularly literature reviews by the ROU, New South Wales’ (NSW) Department of Environment and Climate Change and reports with respect to carbon sequestration.

Table List of main researchers involved in Victorian RO field trials

|  |  |  |
| --- | --- | --- |
| **Market** | **Submarket** | **Author** |
| Intensive agriculture | Market gardening | Cody, Elice-Invaso, Engleitner, Maheswaran, Porter, Surapaneni, Weggler, Wilkinson |
| Viticulture | Schefe, Wilkinson |
| Fruit and orchards | Wilkinson |
| Extensive agriculture | Broadacre cropping | Armstrong, Fisher, O’Halloran, Peries, Stokes, Gill, Clark, Sale, Tang, Norton |
| Pasture | Engleitner, Surapaneni |
| Rehabilitation | Revegetation | Wilkinson |

### Field trial analysis approach

Field trials can be broadly differentiated as either scientific (replicated) or demonstration (non-replicated) trials. Scientific trials are replicated, which means that each treatment is applied to at least three discrete plots of soil. Proving statistically significant treatment effects requires replication. Since demonstration trials are not replicated, the data can’t be considered to be statistically significant. Demonstration trials are much cheaper than scientific trials by an order of magnitude, costing thousands instead of tens of thousands of dollars. They usually compare a (test) strip of treated land to a strip of untreated land and rely heavily on a visual response to demonstrate the benefits of the RO product.

Trials reviewed as part of the commissioned research were shortlisted for general analysis to ensure representation of the following variables to guarantee scientific validity:

1. Conducted by researchers attached to a major research institute or agricultural department
2. Treatments were replicated (at least three plots/treatment)
3. Analysed for significance using accepted statistical techniques
4. Used standard analytical methods
5. Authorship [findings of one researcher (author) confirmed by another].

Most of the findings from trials shortlisted were considered to be valid, apart from the occasional reservation with respect to interpretation of chemical data (associated with poor choice of method or inadequate suite of tests) and claims of significant treatment effects that, on closer inspection, were so small as to be of no practical consequence.

### Trials assessed

The commissioned research evaluated over 100 published and unpublished field trial reports and research papers spanning 1995-2013 focussing on 57 field trials undertaken in Victoria (see Table 2). Approximately 25 interstate trials were reviewed for:

* comparative purposes [Western Australia (WA) and NSW vegetable trials]
* represent benchmark trials [South Australia (SA) viticulture trials] or
* have been identified as priority market segments (e.g., broadacre cropping trials in WA).

For interpretive purposes, a discrete experiment within a project is a trial. This definition is:

* in keeping with the general understanding of a trial
* defensible on the grounds that a farmer will evaluate the impact of the RO product on every crop within a trial
* necessary so that (claimed) effects can be assessed on a crop by crop basis, temporally (seasonal effects) and spatially (effect of soil type, rainfall, management).

*Example: A three year project funded by SV encompassed seven successive vegetable crops (Wilkinson et al. 2009). Soil and yield data was collected for each crop. At the end of the seven crop cycle, long-term impacts were assessed (multiple applications of RO vs. management). Therefore, each vegetable crop represents a discrete trial within a larger project.*

All trials assessed were grouped by submarket (see Table 2) and catchment management authority region (see Figure 1).

Figure Victorian Catchment Management Authority regions



Source: [www.vcmc.vic.gov.au](http://www.vcmc.vic.gov.au)

Table Scientific trials assessed within Victoria by market sub segment and catchment management authority region

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Market** | **Submarket** | **Region** | **Projects** | **Trials** | **Properties** |
| Intensive agriculture | Market gardening | Port Phillip | 13 | 41 | 7 |
| Goulburn-Broken | 1 | 1 | 1 |
| Viticulture | Port Phillip | 1 | 2 | 2 |
| Corangamite | 0 | 1 | 1 |
| Fruit and orchard | Port Phillip | 1 | 1 | 1 |
| Extensive agriculture | Broadacre cropping | Port Phillip | 4 | 1 | 1 |
| Corangamite | 1 | 2 | 1 |
| Wimmera | 2 | 3 | 3 |
| Goulburn-Broken | 1 | 1 | 1 |
| Pasture (grazing) | Port Phillip | 2 | 3 | 3 |
| Goulburn-Broken | 1 | 1 | 1 |
| Rehabilitation | Revegetation | Port Phillip | 1 | 1 | 1 |
| Urban and Amenity | Sport, recreation and leisure | Port Phillip | 1 | 5 | 5 |
|  |  | **TOTAL** | **27** | **57** | **22** |

#

# Recycled organics product evidence summaries

## Intensive agriculture

### Market gardening

An intensive form of agriculture, market gardening, and in particular vegetable growing, can often involve two to four crops cycles per year. As a consequence of frequent tillage, soil structure is degraded and soil organic matter, a key component of well structure soil, is depleted leaving soil carbon reserves low.

Soil type influences performance expectations, particularly with respect to structure. For example in sandy soil, RO products may be applied to improve water and nutrient retention, whereas in a clay soil, improving water infiltration may be more important. However, regardless of soil type, many of the performance expectations of RO products for vegetable production may be similar.

Most of the RO product trials in Victoria have been conducted on market gardening in the Port Phillip region, close to metropolitan composters. The research uncovered 13 projects, encompassing 41 trials, within the two main market gardening districts, which can be differentiated by soil type: poorly structured clays (Werribee Sodosols, also known as red-brown earths) and light-textured sandy soils (Cranbourne and Mornington Peninsula).

Most of the market garden trials tested low nitrogen composted soil conditioners that utilised urban garden waste fortified with a variety of industry derived waste (wool scour waste, coal dust, tannery hair, biosolids) to increase nitrogen levels, and sometimes inorganic ameliorants such as lime or potash lime to increase product pH.

Trial application rates were up to 320 t/ha but commonly 20-40 t/ha. Trial duration in single summer crops typically were 8-13 weeks while winter crops were typically 12-16 weeks. Projects involved successive crops ranging from 2-8 crops over 1-3 years.

Most trials compared multiple products typically comparing composts to conventional management which involved poultry litter and usually testing 1-2 rates. Single product trials sometimes tested very high rates in order to determine ideal rates for maximum productivity but not profitability.

#### Findings

*Providing nutrients*

Few Victorian market garden trials were able to demonstrate yield increases following application of RO products. Rather, numerous vegetable field trials in both sandy and clay soils for both summer and winter vegetables from 1996-2008 demonstrated visually obvious yield decline (Elice-Invaso et al. 1996a, 1996b, 1996c, Engleitner et al. 1997a, 1997b, Wilkinson et al. 2009). The limiting growth factor was commonly attributed to nitrogen being insufficient to meet crop requirements caused by nitrogen drawdown.

Nitrogen drawdown can occur when there is a lot of woody material in the compost or a high proportion of easily degradable carbon components without adequate nitrogen in the substrate. Microbes will draw nitrogen from the soil to break down this material. This can reduce the amount of nitrogen available to plants, resulting in less plant growth or even plant death. While carbon to nitrogen ratio is only one indicator of potential nitrogen drawdown, it was used consistently by all market gardening trials to associate potential nitrogen drawdown effects on reduced yield.

Some market gardening trials (Cody & Maheswaran 1999, Engleitner et al. 1997b) showed that the potential for nitrogen drawdown associated with low nitrogen RO products can be overcome by applying additional inorganic fertiliser although it can be overdone, which can result in crop damage (Engleitner et al. 1997b).

Several trials found increases in soil potassium (K), following application of various RO products. In most cases, the products had been fortified with potash lime (Elice-Invaso et al. 1996, Engleitner et al. 1997a, 1997b) and relatively low rates (20 t/ha, K=0.7%) increased plant K levels (soil K data was not provided). Alternatively, high rates (80 t/ha, K=0.55%) doubled (exchangeable) soil K (Cody & Maheswaran 1998).

Changes in soil calcium (Ca) were not consistent. Cody & Maheswaran (1999) found a decline, while Porter et al. (2010) found an increasing trend that was not statistically significant. Although regular applications of compost would contribute a small amount of Ca to the total soil Ca pool, the major inputs of Ca would still be from lime, which growers apply prior to every brassica crop (1-2 brassica crops annually).

Changes in soil magnesium (Mg) were also inconsistent. Cody & Maheswaran (1999) found relatively low rates of garden waste based compost (20 t/ha) increased (exchangeable) soil Mg above control levels (no compost). Engleitner et al. (1997b) found no effect on soil Mg following rates up to 96 t/ha (Mg=0.2%), while Elice-Invaso found rates as low as 20 t/ha increased plant-Mg (no soil Mg data was provided).

*Soil structure*

Market gardening involves the most frequent tillage of any farming enterprise, with 2-4 crops per year tilled prior to each planting and after harvest, which inevitably cause losses of soil structure and soil carbon. Improvements in soil structure (often measured as bulk density or moisture retention) were typically small and short-term. Longer- term effects (residual for at least two crop cycles) required very high rates of application: around 160 t/ha (Elice-Invaso et al. 1996c, Engleitner et al. 1997a).

Despite the recognised importance of soil carbon to soil structure, few trials have been able to measure statistically significant improvements to structurally related parameters such as slaking, dispersion, bulk density, penetrometer resistance, aeration porosity or water retention. Rates of 20-40 t/ha were too low to effect a measureable change on bulk density, a direct measure of soil compaction, at harvest. A small decrease in bulk density (0.5 kg/L) was detected following 160 t/ha. Inability to detect treatment effects on bulk density at lower rates were attributed by researchers to inadequate sampling intensity: 4 cores per plot. Subsequent soil sampling at harvest of the next crop found no differences in carbon or bulk density, even at high rates.

Of the few trials that have measured improvements, they have not been directly correlated to yield increases. There are several likely reasons for a lack of significant structural effects, and yield improvements:

* Lack of sufficient nitrogen was the most limiting growth factor and restricted the expression of structural benefits on yield.
* Application rates were too low to have an impact on structure in soils that are frequently tilled.
* Soil sampling was not sufficiently intensive.

Some growers use green manure crops to repair soil structure by increasing soil carbon. Wilkinson et al. investigated the possibility of substituting a green manure crop with RO products and found no structural differences (bulk density, soil moisture retention) between the green manure crop and the RO product, i.e., they performed equally well.

*Moisture management*

Two market garden trials investigated the potential benefits of soil conditioners applied as surface mulch. Cody & Maheswaran (1999) found they improved soil moisture retention, but not yields. Porter et al. (2010) investigated the current practice by one leading grower of applying soil conditioner as mulch to reduce the impact of irrigation on surface crusting. Mulching reduced crusting and increased water infiltration rates, attributed, in part to greater earthworm activity.

The trials demonstrated greater soil moisture retention following application of RO products (Cody & Maheswaran 1999, Porter et al. 2010) however this benefit was not quantified in terms of irrigation cost savings. Cody & Maheswaran (1999), found significant increases in both total soil water and plant-available water associated with compost rates as low as 40 t/ha (two thirds incorporated into the soil prior to the formation of the beds and the other third applied onto the surface to give a mulching effect), for the duration of a 13 week trial.

Porter et al. (2010) found that compost increased (sandy) soil water holding capacity but not readily available water (10-40 kPa) and concluded that RO products offered no moisture benefits to plants. However, a soil that holds more water can evaporate more water and as evaporation has a cooling effect may reduce crop stress on hot days.

#### Summary

Trials have showed nitrogen levels in RO products derived from garden waste did not have sufficient nitrogen for market gardening but can assist with soil moisture retention and help reduce the effects of frequent tillage on soil structure and soil carbon.

Research trials in this market have not measured potential savings from decreased use of irrigation water, fertiliser, pesticide or herbicide with a focus on improvements to yield. Until the issue of low nitrogen is addressed, the full potential benefits offered by RO products such as disease control or moisture retention are unlikely to be realised.

Given the higher margins and rotation of crops in this market segment, RO compost producers could target vegetable growers with the objective of sustaining soil organic matter to overcome the issues associated with frequent tillage. Simultaneously testing results for compliance with AS4454-2012 is a baseline for other considerations such as maturity appropriate for application.

### Viticulture

In contrast to agriculture involving annual plants (vegetables, broadacre crops), perennial horticulture (viticulture and orchards) favour the use of surface mulches rather than soil conditioners. The most common soil health benefits associated with surface applied mulches include moisture conservation, weed and erosion control and soil temperature moderation. Better soil health may also translate to cost savings (e.g., irrigation water, herbicide use).

John Buckerfield’s vineyard trials in the late 1990s accelerated interest in composted mulch made from garden organics for viticulture (summarised in Buckerfield 2001). Buckerfield’s work is a testament to the influence of well-promoted positive trial outcomes on expanding the use of RO products within a market segment. Today, mulching is common practice within vineyards.

As a result of mulching being a common practice there have been relatively few scientific RO product trials involving viticulture with seven trials in Victoria reviewed. These trials have been concentrated within two catchments that do not reflect the conditions of all the wine growing regions across Victoria and caution should be taken about extrapolating results, particularly with respect to frost risk.

#### Findings

A single field trial in SA by John Buckerfield in 1990 led to a national project across NSW, Queensland, SA, WA and Victoria. In all states, benefits such as moisture retention, weed suppression and temperature moderation were recorded without impacts on juice quality.

*Weed suppression*

Weed suppression has been reported by all of the mulch trials investigated for this report, including one soil conditioner trial, Armstrong et al. 2007.

*Moisture management*

All of the field trials involving (surface applied) mulch that were investigated for this report reported an increase in soil moisture (due to reduced evaporation). Although these effects on soil are well-established, a direct link to crop yield and quality is less certain because none of the trials differentiated the moisture-retentive effect from the insulation effect of mulch on surface soil temperatures.

*Soil structure*

Other claimed, but less commonly demonstrated benefits include better soil structure (faster water infiltration), which maybe associated with less surface crusting, hence water runoff (because the topsoil remains moist under mulch) and greater biological activity, specifically, earthworms, whose surface feeding habits also help to break up surface crusts and whose burrows create channels for water and for better aeration.

In addition to mulching benefits, Buckerfield & Webster (2001) also claimed substantial soil conditioning benefits: a 25% increase in water infiltration, 30% reduction in soil strength, faster incorporation of surface-applied amendments associated with greater earthworm activity.

*Disease*

There has been some work (Powell et al. 2007) to suggest that mulching with composted garden waste may increase the survival of phylloxera, an insect with the potential to wipe out vineyards. This issue may justify further research but it is suggested that growers should firstly be consulted to establish attitudes to the risk and their proposed management of it, as it may not necessarily be of great concern to some vineyard managers, according to a study by the Phylloxera and Grape Industry Board of South Australia (PGIBSA 2010).

*Frost risk*

Frost is a common concern for viticulturists in that mulch can increase the risk of frost by maintaining cooler soil temperatures under the mulch in early spring. It has been suggested that due to their colour and composition, composted RO mulches may not represent the same frost risk as straw mulches.

Schefe & Slattery (2001) reported no frost damage through the use of mulch but this research was restricted to Rutherglen vineyards. Mulch had no effect on air temperatures 200 mm above the soil surface. Cooler soil temperatures under mulch in early spring did not delay bud burst beyond the most frost prone period. Frost may well be a risk in other zones but this has not been investigated in any trials reviewed.

#### Summary

Sufficient research has been conducted to demonstrate the most commonly reported benefits associated with mulching (moisture conservation/reduced evaporation, moderation of surface soil temperatures and weed and erosion control).

Several trials have linked faster plant growth and greater crop yields to moisture conservation (Buckerfield 2001) and although efforts by other researchers to replicated these responses has been elusive, mulching is now a common part of vineyard management. Mulch trials (viticulture) have established appropriate rates to meet specific objectives (growth rate, yield, moisture conservation, weed control, and soil temperature). From the outset, Buckerfield promoted the importance of product maturity and particle size to meet specific performance requirements, and products were formulated accordingly. The RO products applied as mulch to young vines in Buckerfield’s trials are best described as soil conditioners.

The market is relatively mature, indicated by the fact that managers are well educated, to the point that they’re requesting fit for purpose mulch to meet specific needs, e.g., vine establishment or better vigour, erosion control. Because the market is mature, more scientific field trials are unlikely to expand use of RO products from commercial composters. Demonstration trials are a more cost-effective option for reinforcing the benefits of mulches for viticulture.

### Fruit and orchard

The main fruit and orchard districts in Victoria are the Goulburn Valley (pome and stone fruit), Swan Hill and the Mallee (citrus, and almonds), with a declining contribution from Melbourne (pome, stone, nuts).

RO products are typically provided as mulches to reduce evaporation and soil temperature, and thereby reduce crop stress, which may provide better yields and importantly, better quality (bigger) fruit which attracts a price premium.

For Victoria, only one orchard (mulch) trial was identified (Wilkinson et al. 2000) in the Port Phillip region and therefore a review of 14 orchard trials (scientific and demonstration) across Australia (ROU 2007b) and a five year American trial have been included in the findings.

#### Findings

A review of 14 orchard trials (scientific and demonstration) across Australia (ROU 2007b) found that most researchers reported the usual benefits of moisture retention and weed control, but fewer reported yield increases.

*Moisture management*

Water conservation can be critically important to maintaining water reserves and crop yield, especially in dry seasons. Results from a cherry trial in Gisborne (Wilkinson et al. 2000) found yields were not affected by mulch applications in the first season, as it had only been applied two months previously. However, in the second season, a very dry year in which irrigation water was scarce, yields per tree were doubled (var. Summit). A second variety (Stella) also showed yield increases but they were not statistically significant. It is important to note that growers become more interested in water conservation during droughts. The implication is that they may be more inclined to use mulch in dry years. Also in the Gisborne cherry trial, mulch reduced pooling under irrigation drippers by more than 80% compared to bare ground.

The review of Australian trials (ROU 2007b) identified yield improvements in several crops in trials by Buckerfield and Webster (1999; almonds, pears, cherries, oranges) which reported yield increases in most cases, sometimes dramatically, e.g., a fivefold increase in average orange weight.

Trial data from a five year American blueberry trial (Clark & Moore 1991) found that yield and berry size (and plant growth) responses to mulch were correlated to plant age: mulched plants had higher yields and produced larger plants. Average individual berry weight was greater for mulched plants but only in the first fruiting year of harvest. Mulched plants were much larger at the conclusion of this study, while non mulched plants were stunted although still alive. The authors also reported on another blueberry trial (Spiers 1983) which found that an increase in irrigation applications to non mulched plants reduced the importance of mulching for plant productivity. By turning this finding around, the implication here is that mulch can reduce the need for irrigation. Spiers (1983, citing Spiers 1995) also stated that southern highbush blueberries had much greater root and shoot growth in cool soils (temperature not stated).

*Weed suppression*

Excessive herbicide use (and poor water infiltration) was singled out as a concern by a Victorian cherry orchardist. Field trials (Wilkinson et al. 2000) showed that mulch dramatically reduced weed numbers (weeds/m2), by more than 98%, (65/m2 vs. 8&1/m2 for bare ground, 5&10 cm of mulch respectively).

#### Summary

Moisture-related benefits associated with mulching may apply to all orchard trees (nuts, pomes, stone, citrus). However, nutritional requirements and their effect on crop quality are likely to be crop-specific. For example, Ca nutrition is particularly important to apple quality, while stone fruits have a relatively high nitrogen requirement. The Wilkinson trial also suggests that varietal differences must be considered; yields per tree were doubled, but only in one of two varieties.

Management issues between regions may have differing priorities. For example, frost risk may be less important in temperate areas. Also, orchard managers may prioritise issues differently to agricultural department officers, as suggested by a survey of NSW orchardists (ROU 2006), emphasising the importance of conducting surveys so that field trials correctly identify management priorities of the grower or market.

While greater yields are commonly attributed to better moisture conservation, it is likely that the insulating effect of mulches on surface soil temperature also plays an important role in reducing stress during hot weather, by protecting surface feeder roots.

##

## Extensive agriculture

### Broadacre cropping

Broadacre cropping or cropping, is a less intensive agricultural practice in that it typically involves only one crop per year, mostly under dryland (rain-fed) conditions, and minimum tillage. The main crops grown in Victoria are wheat, barley, oats, triticale, canola, lentils, chickpeas, faba beans, lupins, field peas and vetch. Cropping is practiced across all Victorian regions, but mostly in the low rainfall zones (rainfall <550 mm) of the Wimmera and Mallee.

The research uncovered seven broadacre trials with all seven trials comparing the performance of organic amendments to inorganic nitrogen (urea). Nitrogen is an expensive nutrient that is usually only applied in anticipation of sufficient rainfall that can support extra vegetative growth caused by extra nitrogen. Some trials also compared structural effects (to gypsum); exchangeable sodium percentage, water holding capacity, aggregated stability, compaction, nutrients other than nitrogen (phosphorus, sulphur K) as well as pH and electrical conductivity.

All trials ran for a least two seasons using application rates up to 90 t/ha and as little as 3 t/ha but commonly 10-40 t/ha. Most of the significant Victorian trials were conducted in the Wimmera and involved the surface application of high-nitrogen soil conditioners that utilised urban garden waste and high nutrient waste such as wool scour sludge, piggery bedding litter and biosolids.

#### Findings

*Providing nutrients*

For the Victorian cropping industry the main nutrient inputs are phosphorus and nitrogen. Nitrogen fertiliser is usually not required to get a reasonable yield but under favourable seasonal conditions (normal to above-average rainfall, high soil moisture reserves) the greater yields offered by nitrogen fertiliser justifies the cost. In recognition of the importance of nitrogen to crop yields, broadacre crop trials normally compare RO products to the most commonly used nitrogen fertiliser, urea (47% nitrogen).

The most relevant trial is Norton’s (2000), which compared urea (conventional) to piggery litter and composts made from garden waste/grain sweepings (80/20 and 60/40 blends) with garden waste/piggery litter blends and a garden waste/hair/grease trap waste blend (70/30 and 60/40 blends). Norton (2000) discussed the yield limiting effects associated with the slow release rate of nutrients, as well as the uncertainty of seasonal effects on crop responses to amendments, commodity prices and low annual returns ($250-$500/ha/year), with variable costs of production (seed, fertilisers, herbicides, fuel etc.) of $50-$200/ha (in 2000).

Regarding the use of garden waste based RO products, the main potential yield limiting issue is the same as that faced by market gardeners: low product nitrogen, and the need for supplementary nitrogen.

*Soil structure*

In contrast to RO product trials within market gardening, cropping trials have often demonstrated (grain) yield increases, because they have commonly involved high nitrogen products (manure fortified), and are perhaps best described as fertiliser trials. However, some trials have linked substantial yield increases to better soil structure following application of manure based RO products (manures are typically high in nitrogen and in labile carbon). Recent (since 2007) sub-soiling trials, involving deep slotting of nitrogen-rich RO products (to 30-40 cm depth) have been conducted on broadacre crops, involving rates of around 20 t/ha and increased yields by 1.7 times (Gill et al. 2008, 2009). Results have been so promising that researchers expect to set new yield benchmarks for clay soil in Victoria’s high rainfall cropping zone (>550 mm).

Data presented by O’Halloran et al (2009) found a relationship between lower bulk density and higher soil carbon, but emphasised caution regarding the validity of the data, since it was based on an indirect technique (magnetic resonance imaging). However they did provide data to state, for example, that a 0.5% increase in soil carbon can affect a 10% decrease in bulk density.

More researchers measured (rather than speculated on) an improvement in water stable aggregates than any other structural measurements (Armstrong et al. 2007a, Clark et al. 2009, Gill et al. 2008, 2009, 2012; O’Halloran et al. 2009; Stokes et al. 2003). Several linked higher water-stable aggregates to greater microbial activity (microbial biomass, Armstrong et al. 2007a; respiration rates, Clark et al. 2009; O’Halloran et al. 2009). Several researchers suggested, but did not show greater water infiltration, potentially due to greater earthworm activity.

Although all of the broadacre trials speculated that better crop establishment or higher yields benefits were at least partly due to better structure as a result of adding RO products (a carbon source), few trials actually measured a variety of structural parameters other than bulk density, or linked structural improvements to higher soil carbon. Apart from Armstrong et al. (2007a, 2007b), none of the trials separated fertiliser effects (nitrogen) from structural effects on yield. They found that the benefits were related to soil type, and the impact of RO products on the most limiting yield factor. For soil with good structure, the nitrogen value of the pig litter was more important than the structural value (as measured as better water-stable aggregates, but attributed to better aeration and hence access to subsoil moisture reserves). Proposed work by Gill et al. (subsoil manuring trials) will provide more evidence regarding the component effects of nitrogen vs. better access to subsoil moisture reserves.

#### Summary

Potentially responsive land is defined as soil containing less than 2% carbon, based on the work of O’Halloran et al. (2009), although the definition of responsive could be widened, depending on the most yield limiting factor. For example, some high carbon soils could benefit from application of nutrients within RO products, or a liming effect, or for sandy soils, an increase in cation exchange capacity.

To date, most broadacre trials have had successful outcomes (yield increases), because they have used nitrogen rich products made from animal manures. However, garden waste based RO products are commonly low in nitrogen. Of greater relevance are the broadacre trials that found large yield increases following subsoiling of RO products. The key benefit is better access to subsoil moisture via better soil structure. Greater access to subsoil moisture can be a valuable insurance against extended dry periods. The authors hope to set new benchmarks (Gill et al. 2008, 2009, 2012; Clark et al. 2009).

### Pasture

Pasture farming is more commonly referred to as just pasture or grazing, covering dairy and livestock (beef, sheep meat and wool) production. The dairy industry is Victoria's largest rural industry with the main dairy districts in Victoria within high rainfall zones (>800 mm) in Gippsland in the east, and around the Otways in the south-west (Heytesbury district), although a significant number of irrigated farms remain within low rainfall regions in the North, around Kyabram, Tatura and Kerang. The beef industry is Victoria's second largest agricultural industry and is Victoria's most geographically extensive industry with concentrations in the Western District, Gippsland, Ovens-Murray and Goulburn Districts. Sheep are also widely distributed but are concentrated in the Western District, Wimmera and Central Highlands.

Where RO products are used for pasture production, the main performance expectation has traditionally been a fertiliser effect. RO products are seen as an environmentally friendly alternative to traditional (inorganic fertiliser), particularly with respect to slow release aspects, of the macro nutrients nitrogen, phosphorus and potassium.

There have been few Victorian scientific pasture trials involving RO products, possibly because soils under pasture are typically high in carbon so they may not benefit from the carbon load associated with RO products. All of the trials reviewed were fertiliser trials, where traditional inorganic fertilisers were compared to organic (slow-release) products that are not typical RO products.

#### Findings

*Providing nutrients*

Ronalds et al. (2011) did not present nutrient load data, but 7.5 m3/ha of chicken manure (broiler) applied annually outperformed all other treatments in terms of yield (dry matter) and resulted in higher phosphorus and K levels (in pasture). However, the conventional blend of fertiliser was the most cost effective (2.8 vs. 2.5 cents/kg dry matter). Compost and fish was one of the least cost effective (5.3 cents/kg dry matter). Ronalds et al. (2011) found trace element levels in soil and pasture were unaffected by any of the treatments. Load data was not presented.

Surapaneni et al. (2007) found both superphosphate and fish waste increased soil phosphorus (Olsen). Herbage phosphorus concentrations were generally higher following superphosphate application but there were no differences between the two fertiliser types or among the three fertiliser rates. The authors also stated that the environmental benefits of less residual, readily-available phosphorus (Olsen P) needs to be weighed against the need for additional phosphorus applications to ensure optimum plant production in the following year.

*Soil structure*

Low application rates (less than 10 t/ha) are unlikely to have a (measureable) structural effect in the short term (1-3 years), and especially not in pasture soils which are typically high in carbon compared to regularly tilled soil (vegetables, broadacre cropping). Ronalds et al. (2011) investigated compaction (as penetrometer readings) but data revealed conflicting results, and the authors determined further investigation is needed before any conclusions could be drawn.

*Water holding capacity*

Ronalds et al. (2011) investigated soil water holding capacity (presumably as plant available water although the method was not stated). Data revealed conflicting results, and the authors determined further investigation is needed before any conclusions can be drawn.

#### Summary

All of the trials reviewed were fertiliser trials, where traditional inorganic fertilisers compared to organic (slow release) products that were not typical RO products. The composting industry has been involved in considerable number of demonstration trials in this market but information was unable to be obtained to inform this research report.

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## Rehabilitation

### Revegetation

Revegetation refers to planting exercises commonly associated with roadsides or degraded land and usually involves the use of RO products as mulches to suppress weeds and reduce evaporation, thus providing less competition of ornamentals and improved survival.

For the rehabilitation segment, only one scientific trial was recorded, involving mulch for roadside revegetation.

#### Findings

Wilkinson et al, (2000) demonstrated a 50% increase in survival rate of *Callistemon*, attributed to greater soil moisture and significant weed suppression

#### Summary

Revegetation refers to planting exercises commonly associated with roadsides or degraded land. Only one Victorian research trial was recorded (Wilkinson et al. 2000), involving mulch for roadside revegetation (Port Phillip). It demonstrated a 50% increase in survival rate of *Callistemon*, attributed to greater soil moisture and significant weed suppression.

Given the extent of agricultural land degradation within Victoria, and the potential benefits, the lack of research within this market contrasts with the extent of research in NSW, where approximately 20 trials have been conducted (Kelly 2006).

## Urban and Amenity

### Sport, recreation and leisure

The sport, recreation and leisure market typically includes sporting ovals, parks and gardens, with the main market being in Melbourne. The RO products used within this market segment are commonly composted soil conditioners, either as surface spread mulches (e.g. for establishing and maintain ornamentals) or incorporated or broadcast on ovals as a source of fertiliser, but more importantly to alleviate compaction due to sporting activities in order to provide better grass growth and to provide a softer playing surface.

Little research is available for this market segment. The sporting field trial, involving five sporting ovals and one botanical garden presented below, is best described as a demonstration trial involving paired comparisons (treated vs. untreated). Despite this limitation, analysis of The Healthy Parks & Waterways 2010 program conducted by the Metropolitan Waste and Resource Recovery Group (MWRRG) is valuable because it demonstrates the use of comparative analytical data and the importance of using fit for purpose amendments.

#### Findings

The MWRRG trial suggested that relatively low application rates of RO product (60 m3/ha), provided residual, visible benefits, six months after application. Claims for visible benefits were supported by independent measurements conducted by a turf expert (from Sportsturf). On-site soil physical tests using specialised equipment provided comparative data (treated vs. untreated) of small, but measureable physical benefits to surface hardness. Measurements for soil porosity and moisture were mixed and were insignificant.

#### Summary

The MWRRG trial involving six demonstration trials (five sporting ovals, one botanical garden) found that soil conditioner at 20-100 m3/ha improved soil porosity, moisture retention and drainage (less pooling), resulting in better grass coverage and vigour. Two trials also measured reduced soil hardness which could offer benefits to both plants (root growth) and players (reduced risk of injury).

Given the number of sporting ovals within Melbourne and across Victoria, replicated trials may be justified. However, one of these sites suffered contamination from fine glass. Contamination by fine glass, metals and (hard) plastics may not be obvious until spread, and perhaps impossible to screen out, thus representing a health risk for sporting activities.

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