The use of compost in viticulture

- A review of the international literature and experience -

Environment Australia
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1. Executive Summary

This literature review presents a global overview of the current level of knowledge and the state of play of compost use in viticulture, drawing on research results mainly from Europe and to some extend from North America.

Only a limited amount of information was available that related directly to the use of compost derived from source separated organic waste in viticulture. Therefore the report was complemented with results obtained in related research. It appeared that the organic vine growing industry had a leading role in developing and researching the use of compost in viticulture.

A wide range of municipal and commercial/industrial organic waste materials can be composted with source separated green and food waste being the most common input materials. Biosolids can be co-composted relatively easily with green waste. However this is not common practice in Europe, mainly due to high heavy metal densities in biosolids and potential marketing problems. Most European countries have compost quality standards, which prescribe among a wide range of criteria maximum permissible heavy metal densities. Broadly speaking they are similar to the NSW EPA Grade A Biosolids Standards, except for cadmium which is considerably higher in the NSW Standards.

The use of compost in viticulture can, as in other agricultural/horticultural applications result in a wide range of positive effects. However, there is also scope for potentially detrimental effects.

Positive effects

<u>Supply of humus</u>
The use of compost replenishes soil humus, which is reduced particularly in cultivated soils; in Germany for example at a rate of approximately 4 t/ha per year. Long-term compost use has been shown to increase organic matter levels and it is assumed that compost dressings of 8 – 10 t dry matter (dm) are sufficient to maintain or increase soil organic matter levels.

<u>Supply of plant nutrients</u>
Compost contains all macro- and micronutrients essential for plant growth. However, not all nutrients are readily available in mineral forms for plant uptake. Considerable amounts of nitrogen and phosphorus are organically bound in the compost and are released only once the organic matter is mineralised through microbial activity. The level of readily available mineral nitrogen contained in compost and the degree of nitrogen release due to the mineralisation process following compost application are of particular interest since nitrogen is such an important nutrient for plant production.

Several research projects focused on this aspect but found inconsistent results. In one trial it was established that the use of immature compost provided relatively little additional nitrogen, also during the second year after application while the use of mature compost delivered a flush of soil nitrate, which decreased over time. This positive effect of using mature compost was confirmed by another experiment in vineyards while two others showed that even the use of mature compost provided little additional nitrogen for plant uptake.

In order to reconcile conflicting research results and to solve many open questions related to nitrogen availability and the mineralisation of organic matter, which is important both from a plant nutritional and environmental point of view, a 10 year long-term, co-operative research project was established in Germany. It aims to provide a better understanding of the long-term dynamics of mineralisation and nitrogen supply potential of compost.

Improvement of soil physical, chemical and biological properties

In many experiments it was shown that compost use can substantially improve soil physical, chemical and biological properties, which are often important factors in determining its fertility status. The improvement of these soil properties results often in indirect benefits such as reduced erosion, ease of cultivation, increased fertiliser efficiency du to a higher cation exchange capacity or a reduced disease incidence.

Crop yield and quality effects

Compost use showed inconsistent effects on grape yields, depending on the type of compost used, the vineyard soil and the control it was compared against. A 3-year trial in an organic production system started to show beneficial long-term effects of compost use in the last year of the experiment.

According to the available results, compost use on grapevine makes relatively little difference to the quality of the must or wine generated from these grapes.

Potential negative effects

Oversupply of nutrients

Particularly nitrogen and phosphorus have the potential of causing detrimental environmental effects if compost is used inappropriately. Generally compost does not have high nutrient densities and only a limited amount of the total nutrients contained in compost is immediately plant available. However, if large quantities of compost are used or if compost is applied to soils with high organic matter levels, nitrate leaching can occur. This is a potential problem particularly in viticulture since grapes have relatively little nutrient requirements and, as a survey in Germany has shown, many vineyard soils are already very well supplied with phosphorus.

In Germany the agricultural/horticultural use of compost is limited to a maximum of 10 t dm/ha per year (30 t dm/ha every three years) by way of federal legislation (Compost Decree). In addition, several voluntary schemes operate in various vine-growing regions, which limit the use of organic inputs on the basis of the total nitrogen content of the organic materials or of the soil phosphorus levels.

Heavy metals

Grapevines take up very little heavy metals and very little is deposited in the grapes. Any potential residues are filtered out in wine production, which is why heavy metals do not pose a problem for wine drinkers.

However, high levels of heavy metals can have detrimental effects on plant growth and microbial activity. Heavy metals are, therefore, in a vineyard situation more of concern with regard to the long-term protection and stewardship of the soil. It was shown that sources other than compost can contribute significantly to the heavy metal load received by a vineyard.

Compost use is not only governed by legal regulations. The German Federal Association for Compost Quality, a self-regulating industry body published detailed recommendations that specify compost use in wine growing according to the primary objective of using the compost as well as the soil type, humus content and frequency of application.

It has to be realised that both the soil and the compost represent biological systems whose interaction depends on a range of factors, many of which are not as well understood as previously thought. Compost use tends to show its full potential only after prolonged use. Therefore, many new research projects, which assess the effects of compost use in viticulture, are long-term, running for 5 – 10 years.

To date, Australian research into the use of compost in viticulture has focused on important issues such as water conservation and weed suppression. However, future research into the use of compost should also investigate aspects such as nitrogen mineralisation from compost in various Australian climatic conditions and the release of nitrogen from compost to assess potential detrimental environmental effects if used inappropriately. In this respect it may be helpful to develop recommendations for the appropriate use of compost for various industries. The potential of compost to redress the common phosphorus and mineral deficiency in Australian soils should also be investigated.

2. Introduction

Over the last five to ten years waste management in Australia has seen a major shift from indiscriminate landfilling to the minimisation, re-use and recycling of waste materials. This meant that the domestic and commercial/industrial waste streams were increasingly seen as a source of resources that can be used beneficially.

Organic waste materials (green waste and food waste) comprise the single largest waste fraction in the domestic waste stream and can make up a large proportion in certain industrial waste streams (food processing, catering, tobacco). The separation and utilisation of these waste components, therefore, reduces the amount of waste going to landfill substantially. This can be increased even more if other biodegradable components that are not fit for recycling, such as carton, paper or biodegradable polymers, are collected and processed together with the organic waste materials.

Generally, these organic waste materials are processed through composting or anaerobic digestion if the input materials have a high water content, resulting in the production of compost or digested organic waste. However, since this development was driven almost solely from the waste management side, the marketing and use of the end products always warranted special attention. So far a large proportion of the generated compost was supplied to the landscape industry. However, as more organic waste is diverted from landfills and processed, other markets for compost will have to be found, such as horticulture (Paulin and Reid, 1999; Wilkinson et al., 2000,) or fruit growing (Buckerfield, 1998; Houghton, 1999). Trials in South Australia where compost was used in viticulture have yielded very promising results (Buckerfield, 1998; Buckerfield and Webster, 1999).

Contrary to other agricultural industries, the grape and wine industry is economically very healthy at the moment and is expanding fast. This aspect, combined with the inherent need of vineyards for the importation of organic matter and plant nutrients, makes viticulture one of the prime targets for the marketing and use of compost. Therefore, Environment Australia has decided to fund through its Waste Management Awareness Program (WMAP) nation-wide compost application trials which cover all major grape-growing areas in Australia. These trials are seen as strategically important with regard to the future development of markets for compost and also with regard to defining the costs and benefits associated with the use of compost.

A review of the international literature and experience with regard to the use of composted waste materials in viticulture forms an integral part of this project. The literature review is designed to provide an overview of overseas research results and practical experience gained in countries where the use of compost in viticulture is more widely practised. Australian researchers, the composting and wine growing industry and policy makers can use this information as a basis for discussion and a platform upon which decisions can be based about future activities. The review will influence future research activities and facilitate the focusing of research needs with regard to compost use in Australian viticulture and other industries. To some degree the literature review will prevent duplication of research efforts and therefore speed up progress in compost research and compost use.

3. Historical aspects

Wine has been grown for millennia in Mediterranean countries, from where it spread with the Roman Empire. For most of this time wine was grown through the use of organic waste products, be it residues from winemaking, other vegetative matter, animal manures or the equivalent of today's biosolids. These traditional and proven production techniques were applied also wherever wine production was established in the New World (the Americas, Australia/New Zealand), albeit adapting it to local conditions to varying degrees.

An alternative to managing the soils and nutrient supply of vineyards with organic amendments only became readily available during the 1950's and 1960's in the form of chemically compounded fertilisers. This resulted in a gradual shift of many winegrowers to using chemical fertilisers. There was a parallel development which saw the gradual reduction of livestock on wine growing properties, partly due to the use of tractors and partly due to the fact that nutrients contained in manures were no longer needed.

The composting of manure or other organic matter was not a technology widely employed in central Europe before chemical fertilisers were introduced. In fact, early research into composting and the suppressive effects of compost towards soil borne plant pathogens in East Germany in the 1960's (Seidel, 1961; Reinmuth 1963; Bochow and Seidel 1964; Bochow 1968) came to a pre-mature end due to the use of compost and organic manures being uneconomical in the face of chemical fertilisers.

However, some local authorities introduced the composting of municipal solid waste (MSW) in the 1960's and 70's and where accessible, vineyards were the prime targets for marketing the low quality MSW compost. It had become apparent, most notably in some of the steep hillside vineyards, that abandoning the addition of organic matter resulted in increased erosion and soil degradation. The use of MSW and sewage sludge compost in vineyards was researched and monitored to some extent.

However, due to the poor quality of MSW compost (glass, plastics, heavy metals), which resulted in severe marketing problems, all 20 MSW composting facilities in Germany were either closed down or converted to process other materials. The composting of MSW was superseded by a system where the organic waste materials are separated at source and collected separately before being composted. To date this is the best way of guaranteeing the production of compost with as little contamination and impurities as possible. A report commissioned by the European Union (EU) provides an overview of how far individual Member States had progressed with implementing strategies for the separate collection and beneficial use of organic waste materials in 1997 (DHV, 1997). While some countries such as Austria, Switzerland, Germany, the Netherlands and Denmark were already very advanced as far as the management of organic waste and the beneficial use of compost are concerned, others had not put such a high priority on waste management issues.

The European situation concerning organic waste materials changed fundamentally with the introduction of the EU Landfill Directive in 1999 (EU Website). The Directive, among other specifications requires Member States to substantially reduce landfilling of biodegradable materials in the future. The amount of organic materials allowed into landfill must not exceed 75 %, 50 % and 35 % of the 1995 quantity landfilled by 2006, 2009 and 2016, respectively. A four year derogation period provides countries where more than 85 % of MSW is landfilled with additional time to establish the required processing capacities and markets. This will result in a sharp increase in compost becoming available over the next ten to fifteen years, a considerable amount of which will undoubtedly be used in viticulture, particularly in Mediterranean countries.

4. Methodologies employed

The work on the use of composted organic residues in viticulture that was commissioned by Environment Australia in October 1999 comprises a review of the relevant literature that is available world-wide. It was intended that the literature review would focus on domestic and commercial waste products but not consider agricultural waste materials except for direct by-products from grape growing or wine production. A range of approaches were used to locate useful information:

- Search of the Internet for relevant technical information and links
- Scan composting books and journals as well as conference proceedings
- Make direct contact with universities and research stations which are working either in the field of composting or grape growing
- Make direct contact with organisations and institutions, which are involved in organic wine production
- Make direct contact to known individuals who use or advocate the use of compost in vineyards or who are researching the effects of compost use.

The introductory letter, which briefly outlined the whole project and asked the recipient to forward both scientific and practical information, was sent by mail, fax or email. The response to the search was mixed, with a disappointing return from Italy and Spain. It was not unreasonable to expect considerable information, particularly since both countries are already composting substantial quantities of organic waste and are also engaging in compost related research. The language barrier however may have posed a major problem. The response rate of contacts in the US was also poor and sufficient information was only obtained through a personal contact to a compost marketing consultant the author had met during a conference. Overall, it has to be said that personal contacts to researchers and wine growers who use compost were very important in obtaining information and literature on the use of composted waste in viticulture since relatively little published information is available.

In Germany, source separation and composting of organic garden and kitchen materials started in 1983. Subsequently a considerable amount of research into all aspects of composting and compost use was conducted and practical experience gained. Therefore, a lot of the literature covered in this review originated in Germany. However, a 1997 review of compost use in organic wine growing concluded that, at the time there was very little information available which specifically reported on the effects of composted green waste or bio-waste (kerbside collected organic garden and food waste) on wine growing, while on the other hand a relatively large amount of information was available on the effects of MSW compost (Stoeppler-Zimmer and Petersen, 1999). Even though the situation improved to some degree with more recent research results being available, the report will also make reference to results obtained with MSW compost where appropriate.

5. Input materials

As mentioned previously, this report will not consider animal manures or other agricultural by-products, apart from vine cuttings and by-products of winemaking but will focus on municipal and commercial organic waste materials.

The content of organic matter in MSW varies to some degree from country to country. Avnimelech (1997) estimated that almost 40 % of the waste stream in Europe is comprised of food and garden waste and another 25 % of paper and cardboard, which is also biodegradable and can be co-composted (Figure 1). Therefore, theoretically as much as 65 % of the MSW in Europe could be diverted and turned into a soil amendment product. For environmental and resource recovery reasons, all modern waste management strategies aim to reduce the amount of organic matter going to landfill and instead utilise this potential resource. This is emphasised by the recent European Union Landfill Directive, which requires Member States to reduce the amount of biodegradable waste being landfilled by two thirds over the next fifteen years.

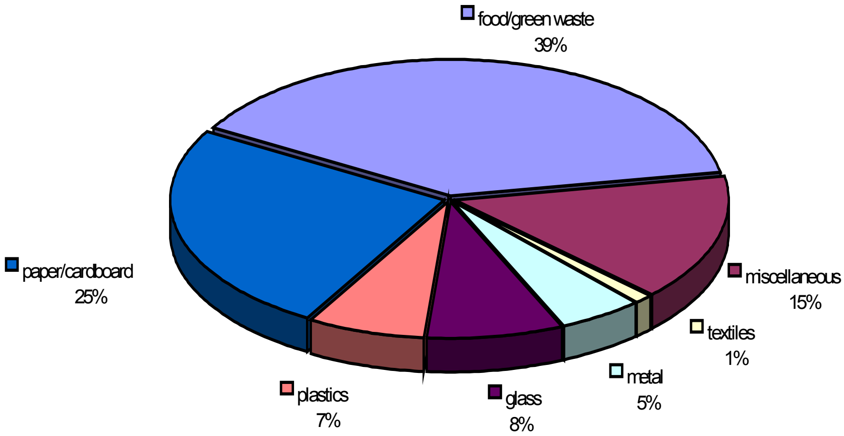


Figure 1: Composition of MSW in Europe (Avnimelech, 1997)

It was shown that the composting of MSW was not an acceptable way of recovering and utilising these organic resources contained in the waste stream since MSW compost is of poor quality and its use unsatisfactory from an environmental as well as from a farming point of view. The organic resource recovery situation changed fundamentally with the trial and introduction of source separation schemes for organic garden and kitchen waste in 1983 (Fricke et al., 1986; Fricke and Vogtmann, 1989; Vogtmann et al. 1989).

Meanwhile, such schemes are a standard waste management feature in countries which acted early to solve their waste management problems, such as the Netherlands, Denmark, Luxembourg, Germany, Switzerland and Austria. Other EU Member States are still in the process of developing waste management strategies and will either adopt the above described model where garden and food waste is mainly co-processed or opt for alternative strategies which focus mainly on garden waste as in the UK (Gilbert and Slater, 2000) or food waste as in Italy (Favoino, 1999).

However, with an estimated total of 60 million tonnes of organic waste being generated each year in the EU, there is no doubt that there is a huge potential for the source separation, composting and beneficial use of organic waste materials. Figure 2 shows that substantial compost quantities can become available in traditional wine producing countries such as France, Italy and Spain and it can be expected that considerable amounts of composted organic waste materials will be used in vineyards in the future.

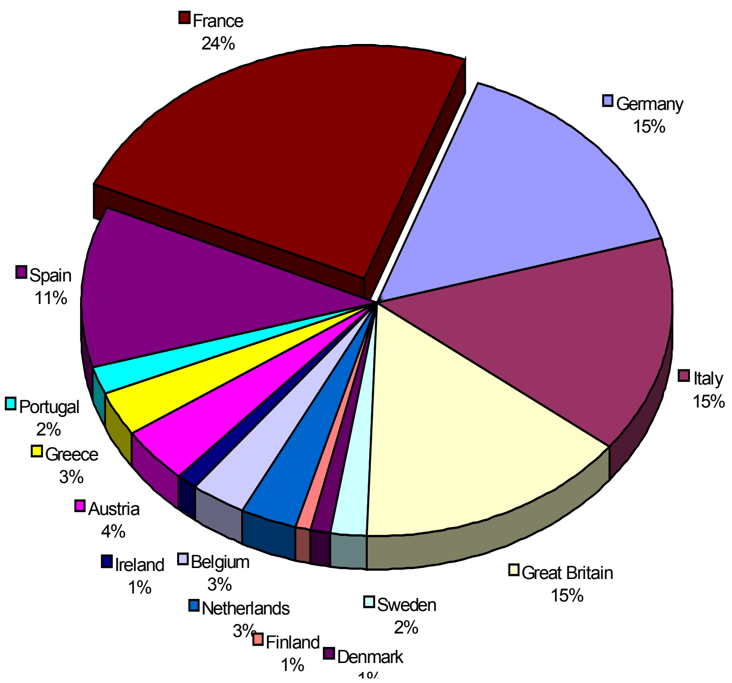


Figure 2: Share of individual EU Member States in estimated total potentially recoverable organic waste stream of 60 Million tonnes per year (DHV, 1997)

Results from Germany show that in 1992 when a total of around 510,000 tonnes of compost were produced, approximately 7.5 % or 38,000 tonnes was utilised in viticulture and fruit growing. Today this could amount to more than 260,000 tonnes, provided the same proportion of the total compost production is utilised in viticulture and fruit growing.

However, compost is not the only organic amendment used by grape growers. Indicative results of a survey (only 43 respondents) conducted in a German wine growing region ("Pfalz") in 1995 showed that the majority of vineyards use residues from wine production as organic soil amendments (Rebholz, 1996). As Table 1 shows, approximately a quarter of winegrowers used animal manure or straw and 35 % used compost.

Table 1: Use of organic soil amendments in the “Pfalz” wine growing region in Germany (n = 43, multiple answers permitted) (Rebholz, 1996)

Organic material	Proportion of farmers using it
Pomace	91 %
Residues from wine production	42 %
Compost	35 %
Animal manure	23 %
Straw	21 %
Bark for mulching	9 %
Coarse residues from waste paper processing	9 %
Sewage sludge, shredded green waste	0 – 2 %

To date, non-European countries recycle mainly garden waste and little food waste unless it arises in large quantities from processing operations. On the other hand, the composting of source separated “yard” waste is common practice in North America as it is in Australia. Therefore, results from these regions will mainly represent results based on the use of green waste compost.

The co-composting of green waste and biosolids is relatively common in the above mentioned countries and the agricultural use of biosolids based products is generally not seen as problematic. In Germany however, the composting industry (which processes garden and food waste) distanced itself right from the outset from sewage sludge, due to its negative image. There, the high level of industrialisation and the ubiquitous presence of potentially toxic elements result in relatively high levels of these elements in biosolids. The use of sewage sludge in agriculture / horticulture is stringently regulated with regard to heavy metal loading, but so is the use of compost. And even though approximately 50 % of sewage sludge is utilised in agriculture, to date in Germany the two waste streams are kept separate. According to some sources, this is done primarily for marketing reasons (Walenzik, 1997).

Depending on the regional availability, other specialised industrial waste products such as paper mill sludge or a wide range of residues from food processing may be available for composting or could possibly be used without prior treatment, as was shown for paper mill sludge in Canadian vineyards (Derkacz, 1999).

6. Compost quality

It is undisputed that the input materials determine compost quality. Table 2 demonstrates clearly that compost derived from source separated organic waste materials (garden and food waste) contains substantially less heavy metals than MSW compost. Furthermore, it is evident that there is virtually no difference in quality between commercially produced bio-waste compost and compost generated in the garden, provided that source separation works properly. Due to the high level of industrialisation particularly in Western Europe, it is not possible to produce compost free of potentially toxic elements. Apart from the effects of ubiquitous pollution, the heavy metal content of compost may vary considerably from region to region, depending on geological conditions and soil types or on past mining activities.

Table 2: Average heavy metal content (mg/kg dm) of various composts in Germany (Stoeppler-Zimmer and Petersen, 1997)

Element	Bio-waste compost 1)	Backyard compost 2)	MSW compost 3)
Lead (Pb)	74	119	513
Cadmium (Cd)	0.7	0.5	5.5
Chromium (Cr)	36	43	71
Copper (Cu)	56	40	274
Nickel (Ni)	27	22	45
Mercury (Hg)	0.2	0.2	2.4
Zinc (Zn)	252	286	1,570

1) Average of 342 analyses between 1994 and 1996,
2) Average of 81 backyard composts collected in the Federal State of Hesse
3) Average of 207 composts

The content of heavy metals in compost is regulated in some but not all European countries. An EU-wide uniform regulation concerning the quality and use of compost is not in place. Such a regulation however is currently being developed and is expected to come into force by 2005. The following table provides an overview of the various standards in different European countries as well as the EU wide Eco-label for soil improving agents. These limits are compared with the current EPA NSW Standards for Grade A biosolids for unrestricted use (EPA NSW, 1997), which are among the more stringent soil amendment regulations in Australia.

Table 3: Maximum permissible heavy metal contents (mg/kg dm) prescribed in compost standards of various European countries, in the EU Ecolabel and in NSW (DHV, 1997, modified and EPA NSW, 1997)

	Lead	Cadmium	Chromium	Copper	Nickel	Mercury	Zinc	Arsenic
Australia (NSW EPA)								
Grade A	150	3	100	100	60	1	200	20
Europe								
EU Eco-label	140	1.5	140	75	50	1.0	300	7.0
Austria								
Class 1	70	0.7	70	70	42	0.7	210	-
Class 2	150	1.0	70	100	60	1.0	400	-
Belgium (Flanders)	120	1.5	70	90	20	1.0	300	
Denmark	120	0.8	-	-	30	0.8	-	-
Germany								
BGK/RAL	150	1.5	100	100	50	1.0	400	-
Blue Angel	75	1.0	75	-	-	-	300	-
Netherlands								
Compost	100	1.0	50	60	20	0.3	200	15.0
High quality compost	65	0.7	50	25	10	0.2	75	5.0

Apart from the heavy metal content, compost standards generally also regulate other potentially undesirable components or effects, such as impurities (including stones), weed seeds, pathogens, maturity, nitrogen draw down and generally negative effects on plant growth. In addition, minimum levels for criteria such as organic matter content, pH, micro and macro nutrients or moisture content are often established. However, compost contains not only components with potentially negative effects but first of all organic matter, which has many essential roles to play in maintaining soil fertility, macro and micro nutrients for plant growth and alkaline substances which counteract soil acidification.

All the above mentioned quality characteristics are largely determined by the input materials processed and to a lesser degree by the composting process or technology employed. Fundamentally, every composting process or technology can produce high or low quality compost; depending mainly on how well the operation is managed. Table 4 demonstrates the difference between composted bio-waste and green waste as it was generated in Germany. Naturally, the nutrient resolution of compost will increase, if materials with a higher nutrient content, such as biosolids, animal manure or certain food processing residues are co-composted, or vice-versa.

Table 4: Average quality characteristics of bio- and green waste compost in Germany (Deutsche Bundesstiftung Umwelt, 1997)

Criteria	Unit	Bio-waste compost[1)]	Green waste compost[1)]
Impurities >2mm	% dm (w/w)	0.19	0.15
Stones	% dm (w/w)	2.17	3.66
Viable seeds/particles	Shoots/l comp.	0.14	0.19
Support of plant growth (25 %v/v)	%[2)]	101	107
Support of plant growth (50 %v/v)	%[2)]	80	98
Level of decomposition[3)]		4.4	5
Organic matter	% dm	37.3	37.0
C/N ratio		15.5	20.1
pH-value		7.96	7.75
Salt content	g KCl/l	7.03	3.68
Nitrogen (sol.)	mg / l fm	341	110
Phosphorus (sol.)	mg / l fm	1410	1065
Potassium (sol.)	mg / l fm	4287	3267
Magnesium	mg / l fm	244	269
Heavy metals[4)]			
Lead	mg / kg dm	74.1	63.5
Cadmium	mg / kg dm	0.0	0.70
Chromium	mg / kg dm	36.1	32.6
Copper	mg / kg dm	55.7	46.5
Nickel	mg / kg dm	25.7	26.8
Mercury	mg / kg dm	0.21	0.19
Zinc	mg / kg dm	252	200

1) Average based on the analysis of 341 bio-waste and 129 green waste composts
2) Dry matter yield in relation to a fertilised, peat based control medium
3) Grade 1 - 5; 1 = immature compost; 5 = fully matured compost
4) Based on an organic matter content of 30 %

Based on a considerable amount of experience with the use of compost, Stoeppler-Zimmer and Petersen (1997) conclude that, in general, one can say that

- Mature compost shows a high level of stable organic humic compounds
- Relative to its organic matter content, compost contains a medium to high level of phosphorus, potassium, magnesium and calcium
- Compared to animal manures the availability of nitrogen is low to medium
- The level of micro nutrients contained in compost is important from a soil fertility point of view.
- The C/N ratio ensures a favourable dynamic for N mineralisation during the growing season. Compost with a high C/N ratio may result in the locking up of nitrogen.
- The abundance of alkaline compounds counteracts soil acidification and the loss of soil structure.
- The organic matter together with the alkaline compounds improve physical soil characteristics (air, water)
- Salinity should not be a problem if compost is used properly.

7. Available compost products

Independent of the wide range of potential input materials used to generate compost, it is possible to differentiate between several compost categories as shown in Table 5.

Table 5: General compost categories

Category	**Types of compost**
Nutrient status	Nutrient poor compost generated from woody green waste *vs.* Nutrient rich compost generated from green waste (high in grass clippings), bio-waste, biosolids, animal manures etc.
Particle size	Fine compost for horticulture (e.g. < 10 mm) *vs.* Medium compost for field application (<20 or 30 mm) *vs.* Compost for mulching (e.g. 20 - 60 mm)
Level of stabilisation	Pasteurised compost (semi-matured) *vs.* Fully matured compost

In the marketplace these categories are not clear-cut and overlap to a large degree. This is due to product diversification that facilitates the expansion of the compost market by ensuring that the diverse needs of as many compost users as possible are met.

8. Use of compost in viticulture

This section of the literature review (Sections 8. – 8.1.2.5.) is predominantly based on a report by Stoeppler-Zimmer and Petersen (1997) and results from Germany. Other sources or results from other countries are quoted or indicated appropriately. With regard to sampling dates please note that European seasons are reverse to the Australian seasons.

Currently, there are relatively few results available, which relate specifically to the use of source separated organic waste materials in viticulture. However, to a large extent it should be possible to transfer and extrapolate many of the fundamental effects observed with the use of different composts (e.g. from animal manure or MSW) or in different cropping systems. Therefore, this review will draw on information, which may be outside the brief of this project, but still be considered valuable information in the context of the project.

It has to be understood that compost itself and the soil it is applied to represent biological systems which can vary greatly and react differently under different environmental conditions. Therefore, the use of compost does not necessarily show uniform results but is determined to a large extent by the following parameters:

- the characteristics of the applied compost or compost product,
- the prevailing environmental conditions at the application site (climate, soil type),
- the subsequent cultivation of the soil, if performed and
- the crop.

This may explain differing or even conflicting results presented in this section of the review.

8.1. Positive effects of compost use

8.1.1. Overview

The use of compost has direct and indirect effects on grapevines. While direct ones such as the supply of nutrients or yield and quality effects may be easily quantifiable, the indirect ones which support general soil fertility are harder to assess. Generally, a fertile soil is associated with a high organic matter content.

It is undisputed that compost provides far more beneficial effects than just the supply of nutrients. The following list of soil and plant characteristics which may show positive effects in response to compost use will be discussed in more detail in the following sections:

<u>General effects</u>
Humus
Soil fertility
Yield
Produce quality

<u>Effects on physical characteristics of soil</u>
Pore volume
Water storage capacity
Aeration
Soil structural stability and resilience to permanent soil deformation

<u>Effects on soil biology</u>
Mineralisation
Bio-structural soil stabilisation by soil organisms
Suppression of pathogens

<u>Effects on chemical characteristics of soil</u>
pH - value
Nutrient sorption capacity
Plant available macro nutrients
Capacity to slowly release macro nutrients
Micro nutrients

8.1.2. Supply of humus

Soil organic carbon and humus (or organic matter) contents are generally determined through essentially the same chemical analysis and are differentiated by the following conversion factor (Mueller-Saemann (1986):

$$\textit{Humus} \xrightarrow{x\ 0.58} \textit{organic Carbon} \xrightarrow{x\ 1{,}72} \textit{Humus}$$

Organic carbon refers to the carbon bound in organic substances in soil, whereas humus or organic matter not only contains organic carbon but also organically bound nitrogen and other plant nutrients and minerals. In Australia 'soil organic matter' is the term most frequently used, while in Europe the term 'humus' is also used. In this context, both terms refer to all types of organic matter, whether they are well decomposed or not. Some confusion may occur because 'humus' is also used to describe a particular component of organic residues that has been well decomposed and is relatively resistant to further degradation. The size of this component can only be determined by fractionation of organic residues into various 'pools'.

When the use of compost and other organic soil amendments are considered, particularly their longer-term effects and their ability to store and release plant nutrients, it may be appropriate to examine their effects on the various pools of soil organic matter, which all have different roles to play in soil.

In this report both organic carbon and humus levels are used, reflecting their use in the original literature.

Agricultural activities, particularly the soil cultivation, reduce the level of humus, which in Germany amounts to approximately 4.4 t/ha per year, on average. For vineyards it is estimated that approximately 4 t/ha per year of humus is lost on medium to heavy soils, 6 t/ha per year on light soils and 8 t/ha per year on rocky and steep soils (LLFA Neustadt, undated). It is estimated that, on average vineyards in Germany require approximately 4 t/ha per year of organic matter (dm) to maintain their humus level.

Generally, the use of compost results in increased humus or organic matter levels in the soil. Due to the high organic matter content of compost and compost products (20 – 50 % dm) it is possible to meet the needs of the soil with an annual compost application of 8 – 10 tonnes (dm), if crop residues are retained. Mature compost contains a higher level of stable organic compounds that aid the formation of humic compounds and hence humus, while not fully matured compost was found to have a more stimulating effect on microbial activity in the soil.

Between 1970 and 1974 a trial was conducted where MSW compost was applied to Riesling grapes at rates between 35 t/ha per year and 200 t/ha every three years. Prior to compost application, the vines received a base application of mineral fertiliser (200 kg/ha N, 80 kg/ha P_2O_5 and 250 kg/ha K_2O). After five years the humus content of compost amended soil had increased to levels between 3.5 % and 6 % while soil without compost showed only 1.5 %.

A four year trial on agricultural soil showed that more moderate compost application rates over a period of time can also increase soil organic matter levels substantially (Table 6). Although all treatments showed higher organic matter levels than the control, it seems somewhat surprising that the level 2 bio-waste compost application does not show higher organic matter readings than level 1.

Table 6: Effect of compost amendment on soil organic matter content and pH (Gottschall, 1991, adapted)

Treatment	**Total soil organic matter (%)**		**pH-value**
	Carbon	**Humus**	
Control (unfertilised)	0.84	1.68	5.7
Composted manure - Level 1	0.96	1.92	5.9
Composted bio-waste - Level 1	1.09	2.18	6.0
Composted manure - Level 2	1.05	2.10	6.0
Composted bio-waste - Level 2	1.03	2.03	6.6

Notes:
Level 1 = annual average compost application of 15 t/ha fm (= 9 t/ha dm)
Level 2 = annual average compost application of 30 t/ha fm (= 18 t/ha dm)
Effects after 4 years treatment

8.1.3. Supply of plant nutrients

The considerable amount of nutrients contained in compost will result in a direct effect on plant growth, which is why the nutrient requirements of grapevines should be taken into account when compost is used. Grapevines have relatively little demand for nutrients, which depending on yield, variety and author are in the following range:

	Loehnertz, 1988	Kadisch, 1985 (at yield of 12 t/ha)
Nitrogen:	35 - 80 kg/ha	100 kg /ha
Phosphorus:	10 - 25 kg/ha	30 kg/ha
Potassium:	70 - 100 kg/ha	120 kg/ha
Magnesium:	8 - 15 kg/ha	30 kg/ha

The nutrient budget in Table 7 shows that a compost application of approximately 10 t dm/ha (20 m^3/ha), which may be compounded to one application every two or three years, is sufficient to meet this demand, except for nitrogen. However, it can be assumed that the apparent lack of nitrogen in the nutrient budget is supplied through airborne nitrogen deposits associated with precipitation (30 – 50 kg/ha per year) and also through mineralisation of soil humus reserves.

Most, or a high proportion of phosphorus, potassium, magnesium and calcium found in bio-waste and green waste compost is available to plants immediately or becomes plant-available over time. Approximately 20 % of phosphorus in compost reacts like P in mineral fertilisers and is immediately available for plant uptake while the remainder is more strongly bound and will become available later (Peretzki, 1994). Virtually all potassium supplied with compost can be used immediately by plants.

Table 7: Availability and supply of nutrients contained in 10 t dm/ha (20 m^3/ha) of an average bio-waste compost in comparison to the nutrient demand of grape vines

Nutrient	Nutrient concentration (% dm)	Nutrients available to plants in kg/ha (Percentage of total)		Nutrient demand of vines [1)] in kg/ha per year
		In first year	Within four years	
N	1.2	10 –20 (10 – 15 %)	approx. 50 (approx. 40 %)	45 – 80
P_2O_5	0.7	20 – 30 (30 – 40 %)	70 (100 %)	16 –23
K_2O	1.2	70 – 100 (65 - 85 %)	120 (100 %)	83 –100
MgO	1.8	10 – 30 (5 - 15 %)	?	10 – 151
CaO	6.0	sufficient	sufficient	15 - 40

1) Average yield: 10 t/ha grapes, 2.7 t/ha (dm) shoots and cuttings

The situation is different and more complex with nitrogen of which only a small proportion is directly available to plants initially and the remainder being mineralised and released only over time (3 – 4 years). As a rule of thumb it is generally assumed that approximately 5 % of the total amount of nitrogen found in compost is present in a mineral form and hence directly plant available and that approximately 10 %, or less, of the total nitrogen is mineralised annually over the next few years (Bundesgűtegemeinschaft Kompost, 1992; Peretzki, 1994). It is estimated that in total approximately 40 % of all nitrogen contained in compost at the time of application will become available for plant uptake (Bundesgűtegemeinschaft Kompost, 1992).

The rate at which organic compounds are mineralised and nitrogen is released depends largely on the nitrogen level and maturity of the compost (degree of stabilisation) as well as on the environmental conditions in the field. A field trial in a horticultural environment studied the different rates of nitrogen release from mature and semi-mature compost. Both immature and mature compost was applied in autumn at a rate of 100 t/ha. Soil nitrate levels (NO_3) were measured during the two subsequent winter periods, when nitrate leaching is most likely to occur. Results showed clearly that the nutrient loading of the mature compost was considerably higher than that of the semi-mature compost but it also became apparent that the dynamic of nitrogen mineralisation was different for the two composts (Figure 3). The plots that received semi-mature compost showed almost identical nitrogen availability dynamics as the control that had not received any compost.

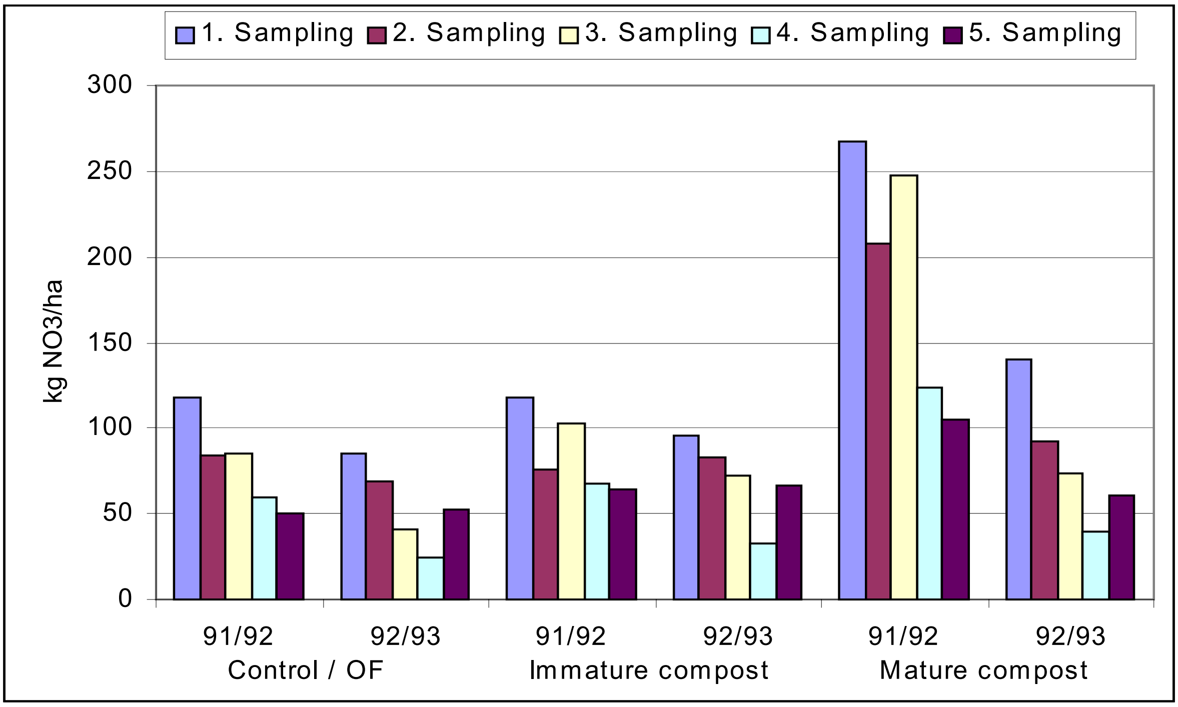


Figure 3: Development of nitrate contents in a horticultural soil (0 – 90 cm) amended with 100 t/ha mature and semi-mature compost in autumn 1991 during the following two winter periods (OF = commercial organic fertiliser, applied in March 1993) (Petersen and Steoppler-Zimmer, 1996 in Stoeppler-Zimmer and Petersen, 1997)

An assessment of nitrogen availability from compost in tropical conditions showed that during a trial period of 31 weeks the nitrogen efficiency (proportion of available N transformed into plant growth) from composted chicken manure measured about 30 % and that of composted slaughter house waste about 21 %, compared to an efficiency of 46 % for urea (Schuchardt and Sunarlim, 1999). The nitrogen dynamics in this pot trial with elephant grass were quite different for the three nutrient sources. Surprisingly, according to plant growth results, composted chicken manure provided more nitrogen than urea during the first seven weeks of the trial and generated a flush of growth which peaked after nine weeks simultaneously with that of urea fertilised plants and at almost the same level (Figure 4). Subsequently, from week nine to week sixteen urea showed the best plant response while from week nineteen until the end of the trial (week 31) both composts sustained better plant growth than urea with composted slaughter house refuse showing a slight advantage over composted chicken manure.

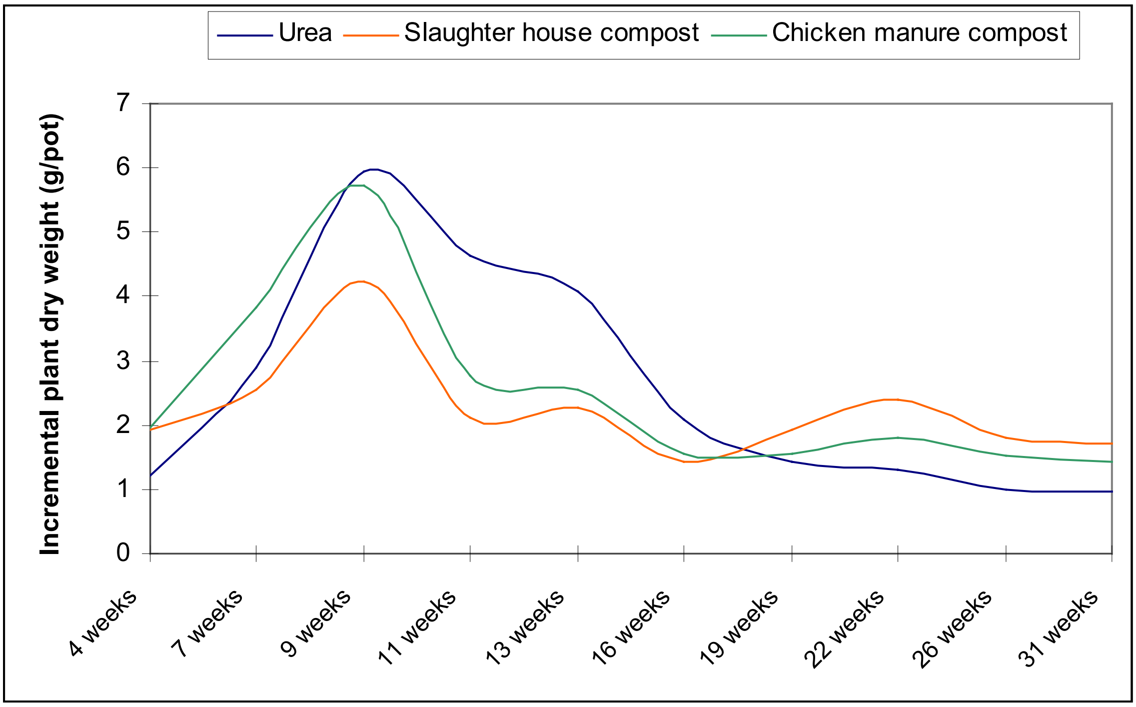


Figure 4: Effect of inorganic and organic nutrient sources (2 g N/12 lt. pot from each source) on plant growth in tropical conditions (Schuchardt and Sunarlim, 1999)

In Europe there is considerable interest in the nutrient and mainly nitrogen dynamics associated with the use of compost. This interest stems from an agronomic and plant nutritional interest but also seeks to address potential environmental hazards caused by nitrate leaching and ground water pollution. These potential environmentally detrimental effects of compost use are addressed in more detail in Sections 7.2.1. – 7.2.3.

Due to the relatively low nutrient requirements of grapevines there is a concern that the use of organic products, often in addition to mineral fertilisers results in an oversupply of nutrients. The effect of various soil amendments (bark, straw, compost, farmyard manure) and management practises (open ground with winter cover crop and permanent cover crop in every second row) on the content of mineral nitrogen in the soil was assessed during 1999 (Schwab, 1999). Preliminary results are shown in Figure 5 and they demonstrate that the use of bio-waste compost (30 and 50 t dm/ha) can result in soil mineral nitrogen levels between 200 and 250 kg N/ha, which is approximately three to four times as much as the average requirements of grapes (approx. 60 kg N/ha).

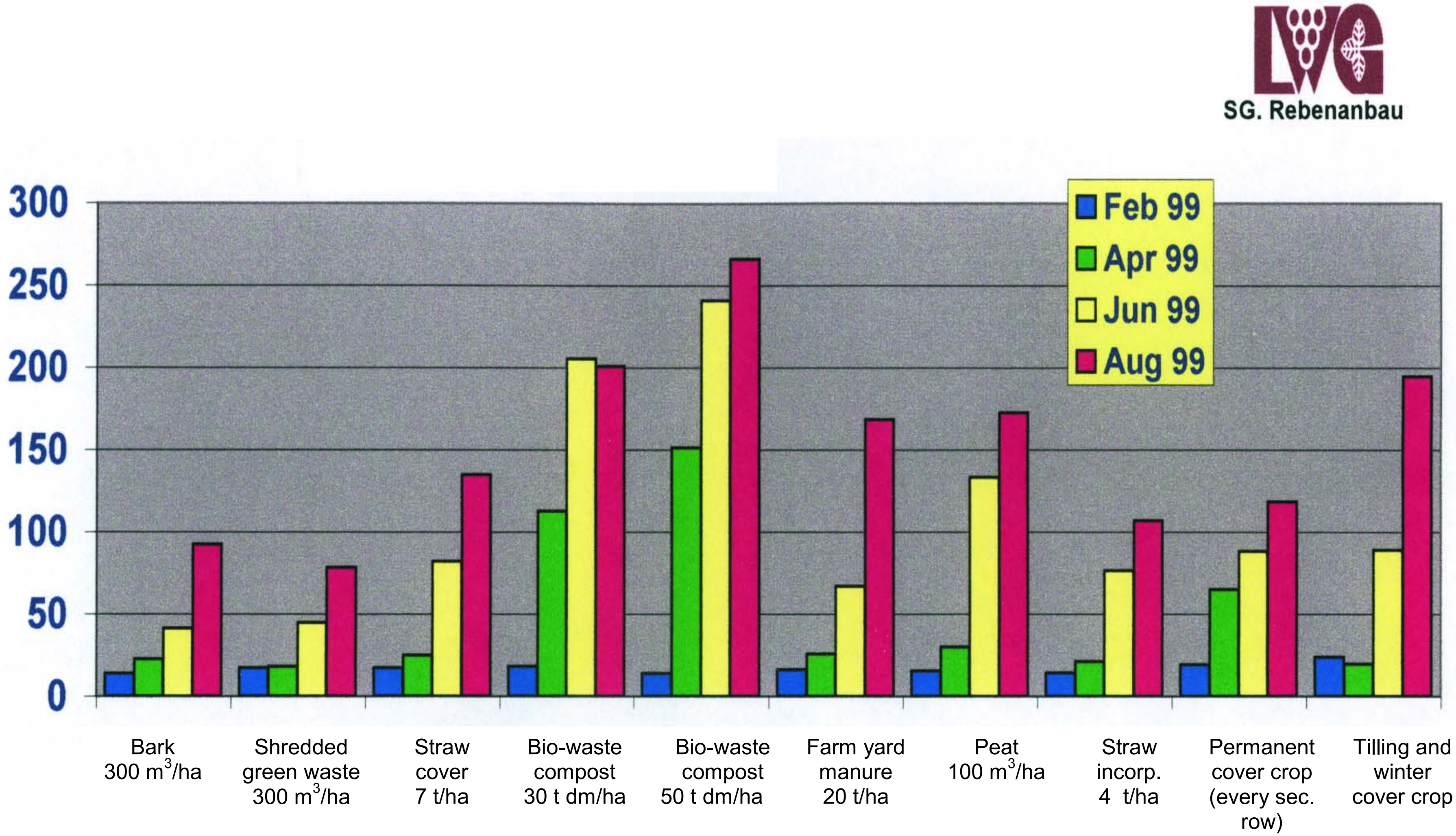


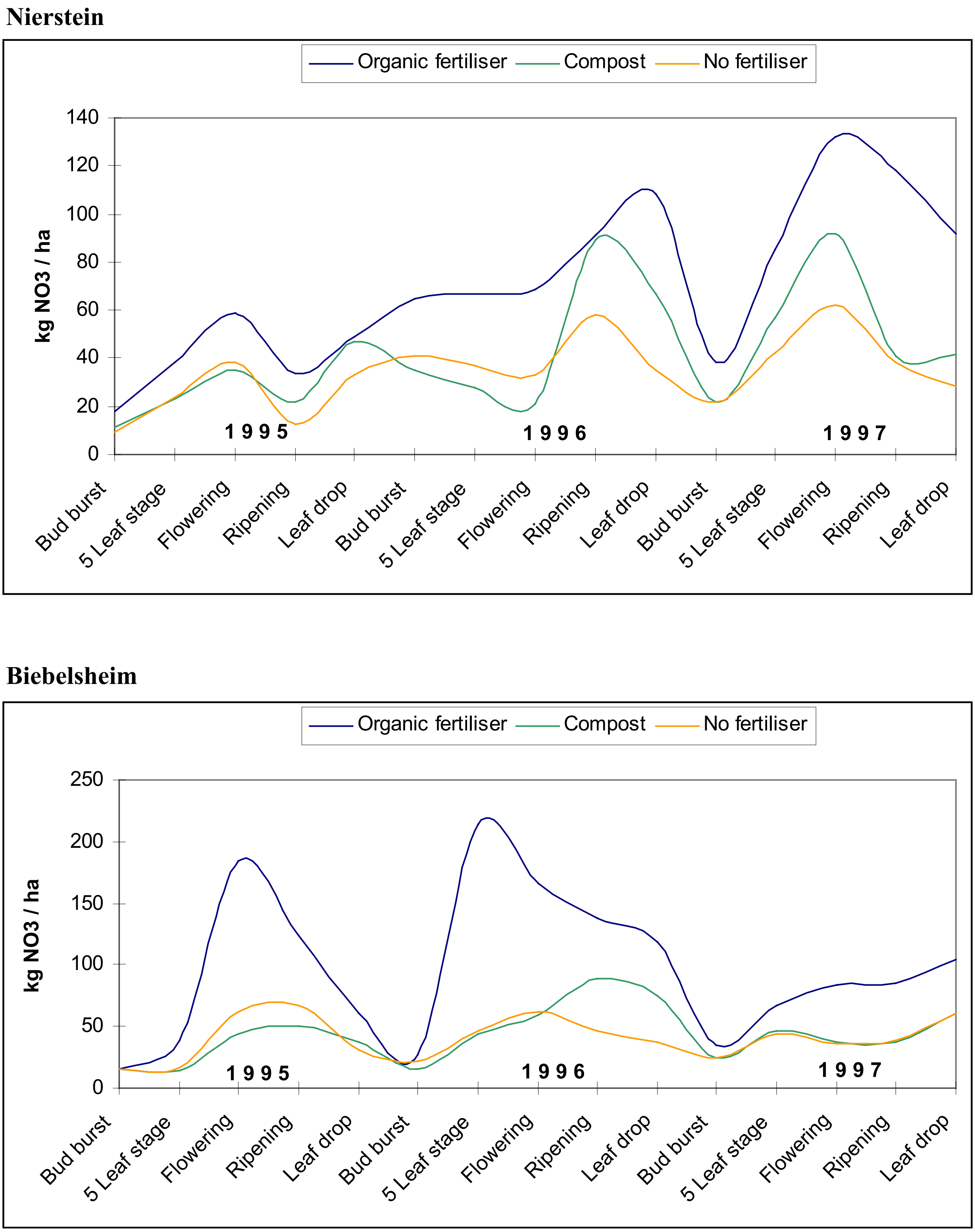
Figure 5: Effect of spring amendment of vineyard soil with various organic products and different management techniques on soil mineral nitrogen content (kg/ha) (Schwab, 1999)

However, two longer-term trials, which are presented below, showed very different results to those obtained by Schwab (1999).

In an attempt to assess different nutrient sources for organic vine growing, Hofmann (1998) monitored the effects of using compost and an organic fertiliser on the soil nutrient status and various yield and quality parameters in two different vineyards. The organic fertiliser had total nitrogen content of 5 % while the compost analysis showed a level of 1.4 %, of which approximately 5 % were assumed to be immediately plant available. With values between 1.2 and 2.8 %, the Biebelsheim vineyard showed relatively high humus levels (top 30 cm), while those found in the Nierstein trial site were even higher with humus contents between 3.4 and 4.3 %.

Both products were applied to supply 50 kg of plant available nitrogen per year to the vines. However, in both locations the use of the organic fertiliser resulted in a considerably higher soil nitrate level than was observed where bio-waste compost was used (Figure 6). While this was particularly evident during the first two years of the experiment at the Biebelsheim site, no considerable difference was observed in Nierstein until the third year. The high nitrate levels of more than 200 kg NO_3/ha that resulted from organic fertiliser use are explained by the stimulation of microbial activity, which results in increased humus mineralisation (priming effect) and subsequent nitrogen release.

Such an effect was not observed where compost was used. Certainly in Biebelsheim and for the first one and a half years in Nierstein, the use of compost did not result in an appreciable increase in soil nitrate levels, and was very similar to the unfertilised plots. At times compost plots showed even lower NO_3 levels than the control plots. This is an indication that the compost did not provide additional nitrogen for plant growth during these periods but instead required soil nitrogen for further degradation. The compost used in these trials was commercially available mature bio-waste compost which can be expected to release nitrogen and not show a nitrogen draw down effect as observed in these trials.



Note: Organic fertiliser applied annually to provide 50 kg N/ha
Compost applied at 40 t/ha (fm) at beginning of trial, assumed annual N availability = 50 kg/ha

Figure 6: Effect of bio-waste compost and organic fertiliser on soil nitrate levels (0 – 60 cm) in two vineyard soils over a three year period (Hofmann, 1998)

The results presented by Hofmann are confirmed by similar data obtained during a six-year trial in which different organic amendments were applied to a vineyard between 1994 and 1999 (Schwab, 1999). Figure 7 demonstrates that only chicken manure and to some extent farmyard manure showed distinct effects on soil nitrogen levels, mainly during the year of application. The use of bio-waste compost showed little difference to the nitrogen levels found in the unamended control plot, except for 1999 when the compost amendment resulted in a significant increase of soil nitrogen.

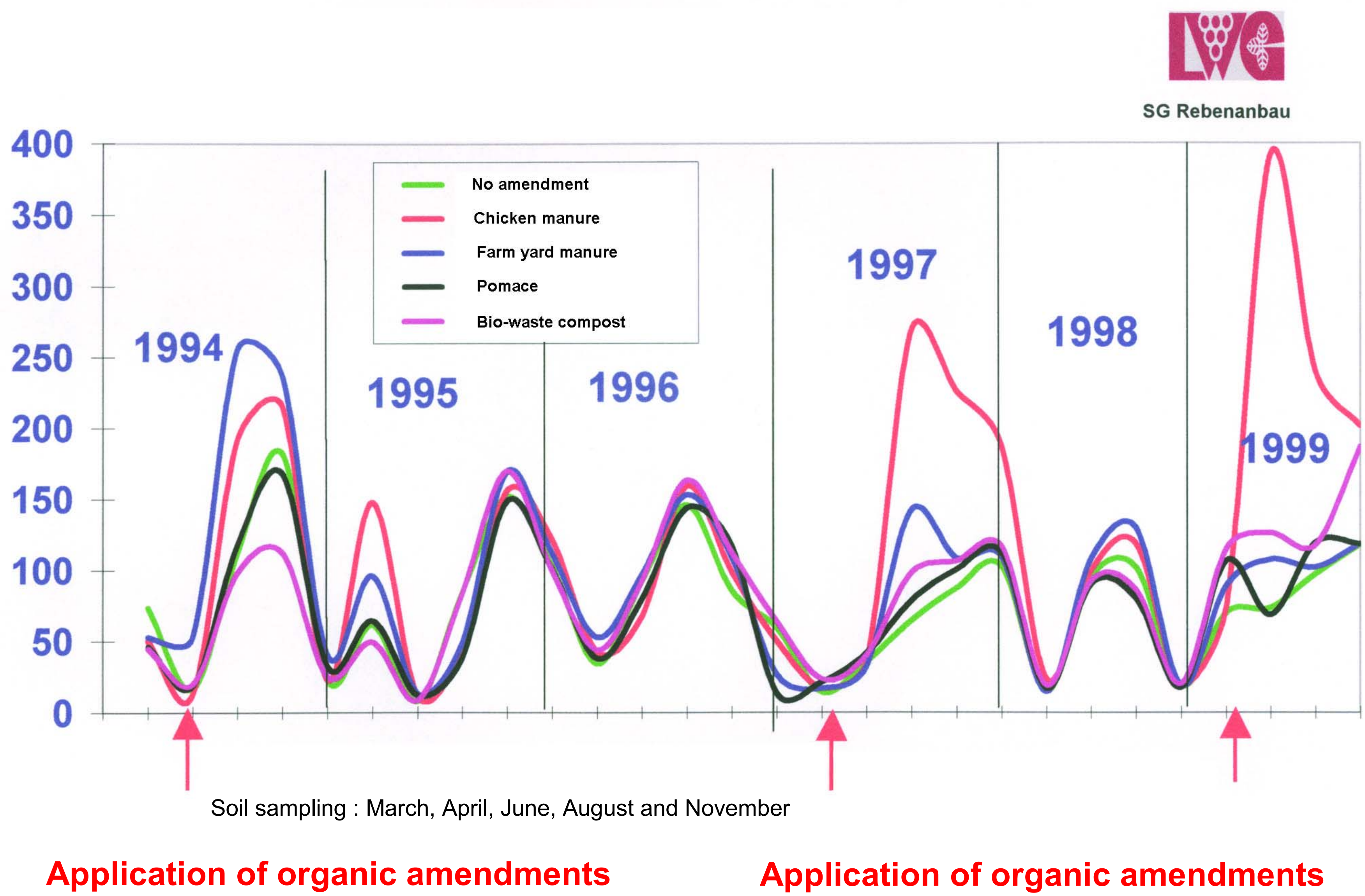


Figure 7: Nitrogen mineralisation (kg/ha, 0 – 60 cm) as a result of different organic amendments to vineyard soils (Schwab, 1999)

The net effect of the various soil amendments is shown in a nitrogen budget covering the six-year trial period (Figure 8). It is apparent that the nitrogen effects of all organic soil amendments can vary considerably with farmyard manure being the most consistent and chicken manure resulting in the highest relative mineralisation rate (almost 200 %), compared to unamended soil. In the first year after its application, bio-waste compost resulted once in nitrogen draw down (1994) and twice in a net increase (33 % and 49 % in 1997 and1999, respectively) compared to the level of nitrogen mineralisation observed in the unamended control plot. Surprisingly, in 1998, the second year after compost application, a nitrogen draw down effect was recorded even though that was not the case when the compost was applied in 1997.

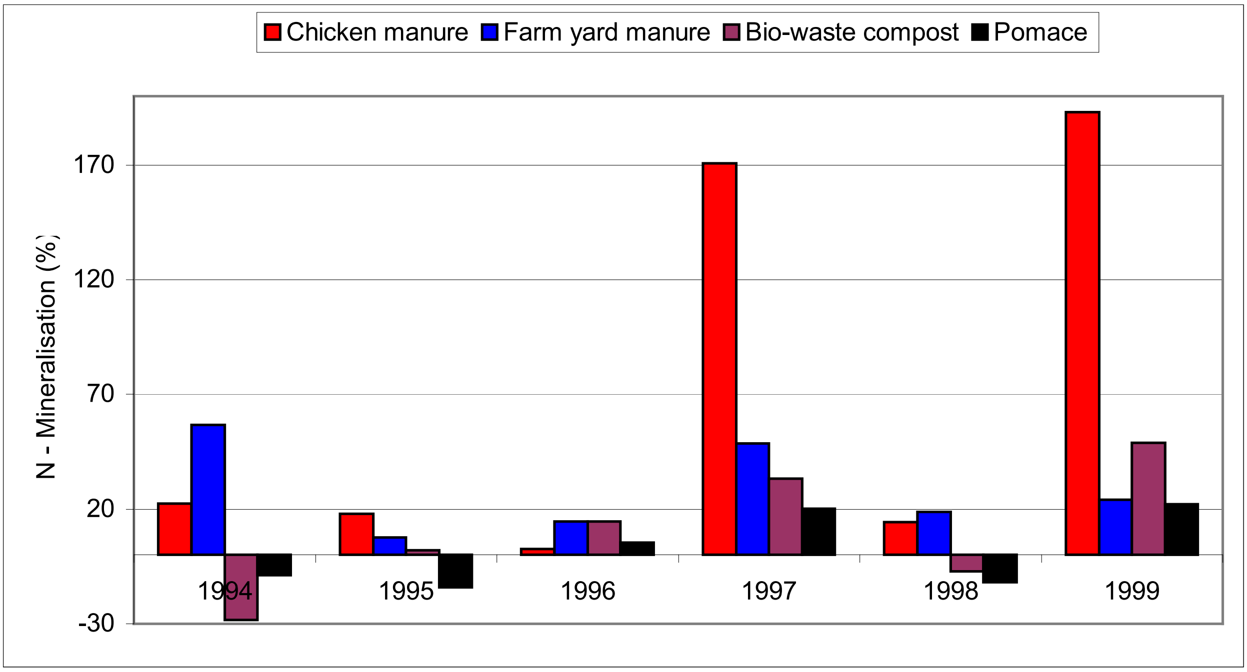


Figure 8: Nitrogen mineralisation rate in a vineyard soil (0 – 60 cm) amended with various organic products in relation to the unamended control plot (Schwab, 1999)

8.1.4. Improvement of soil physical properties

The physical characteristics of soil are an important factor in determining its fertility status. Positive readings are desirable, particularly for the following parameter:

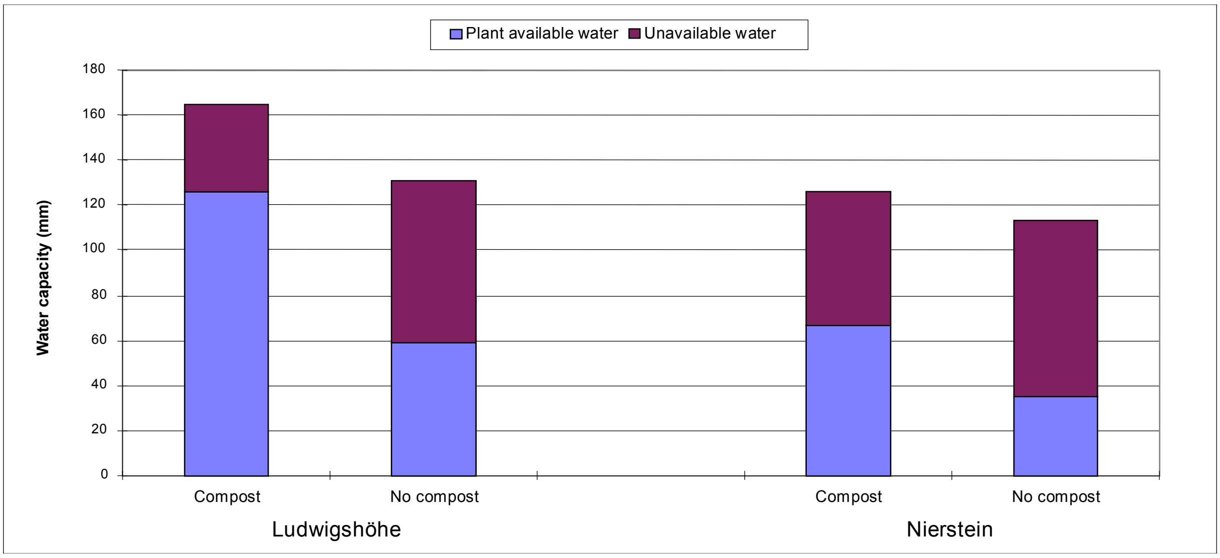
- Pore volume
- Proportion of airfilled pore space
- Plant available water capacity
- Aggregate stability
- Resilience to soil deformation
- Ease of cultivation

Numerous trials with compost made from manure, MSW, sewage sludge, green waste and bio-waste have shown the positive effects of compost on soil physical properties. It has been shown that the use of compost as a soil amendment improves soil pore volume, the proportion of aerating and draining pores, the water holding capacity, the aggregate stability and as a subsequent effect also reduces soil crusting and erosion. Table 8 shows the effects of compost on pore space and water holding capacity in three vineyard soils and it can be seen that the proportion of aerating pores is also increased in water logged soils. It is unclear however, why compost use in vineyard III resulted in a reduced water holding capacity.

Table 8: Effect of MSW compost on physical properties of three vineyard soils (Banse et al., 1972 in Stoeppler-Zimmer and Petersen, 1997)

Location	**Pore volume in %**	**Proportion of aerating pore space**		**Water holding capacity in % (v/v)**
		Natural moisture content in %	**Water saturated in %**	
Vineyard I (with compost)	56.9	25.9	17.1	39.8
Vineyard II (without compost)	48.3	20.0	12.6	35.7
Vineyard III				
- with compost	64.9	36.1	24.5	40.4
- without compost	61.0	27.0	18.5	42.5

By applying 400 m^3 of composted sewage sludge in two vineyards the effect of compost on the water status of vineyard soils was assessed. This relatively high application rate showed that compost use not only increases the water holding capacity of soil but, more importantly, it also greatly increases the proportion of plant available water (Figure 9).



Note: location is two vineyard soils in Germany (0 - 60 cm depth).

Figure 9: Effect of compost use on water-holding capacity and plant available water of two vineyard soils (Krieter 1980 in Stoeppler-Zimmer and Petersen, 1997)

Many vineyards in Europe are on slopes or line steep valley sides, particularly in Germany and Italy, which means that erosion is a constant problem. For this reason, the above trial was predominantly designed to measure the effects compost may have on the level of erosion occurring in vineyards. The results shown in Table 9 demonstrate that the use of compost can reduce soil erosion substantially, in this case even to zero soil loss. The reduction of soil erosion, the proper management of the soil water status and the sufficient supply of organic matter are considered paramount for vine growing on steep slopes.

Table 9: Effect of compost use on soil erosion (soil loss) in two vineyards during 1975 (Krieter 1980 in Stoeppler-Zimmer and Petersen, 1997)

Date of storm event	**Rain (mm)**	**Soil loss in tonnes**			
		Vineyard Nierstein		**Vineyard Ludwigshoehe**	
		No compost	**Compost**	**No compost**	**Compost**
21. June	9	0.3	0	0.6	0
5. July	28 (in 30 min.)	14.0	0	12.5	0
10. August	13	0.6	0	1.2	0
12. August	13.5	0	0	0.4	0
17. August	28	0	0	1.2	0
31. August	25 (in 30 min.)	7	0	9.0	0
Total soil loss					
Trial plot (500 m^2)		21.9	0	24.9	0
Per hectare (10,000 m^2)		438	0	498	0

8.1.5. Improvement of cation exchange capacity and pH increase

The cation exchange capacity inherent to organic matter is particularly important for sandy soils that are low in colloids while it is still beneficial in other soils, too. Compost is reported to substantially increase the cation exchange capacity in soils.

Acid rain in Europe has resulted in increased soil acidification, which makes the use of alkaline soil amendments particularly desirable. Due to the high level of alkaline compounds in compost it is possible to increase the soil pH considerably through the use of compost. An agricultural field trial showed that the annual application of 15 and 30 tonnes (fm) of composted bio-waste and farmyard manure over a four year period raised the pH of a moderately heavy soil (14.7 % clay, 80.5 % silt, 4.8 % sand) from pH values of 5.7 to levels between 6.0 and 6.6 (Table 6, page 15).

8.1.6. Increase of soil biological activity

The biological parameters play a very important role in the concept of soil fertility. It is generally accepted that the amendment of soil with organic matter, for example compost, improves the environmental conditions of soil microorganisms and hence the soil biological activity. The same holds true for earthworms, as was shown for example in California (California Integrated Waste Management Board, 1997).

An increase of soil biological activity through compost use was confirmed for macro-organisms (Collembola) in a trial that assessed the effect of various composts on these organisms. A trend was observed which indicated that bio-waste compost showed better results than composted farmyard manure.

Another field trial where soil microbial activity was measured through the level of FDA (fluorescein diacetate) hydrolysis showed very clearly that the use of bio-waste compost increases the microbial activity in soil (Figure 10). It furthermore revealed that semi-mature compost stimulates soil microbial activity more than is the case with fully matured compost. The higher compost application (100 t fm/ha) yielded the highest microbial activity, which alongside all other treatments (including the control) decreased from early summer through to late summer.

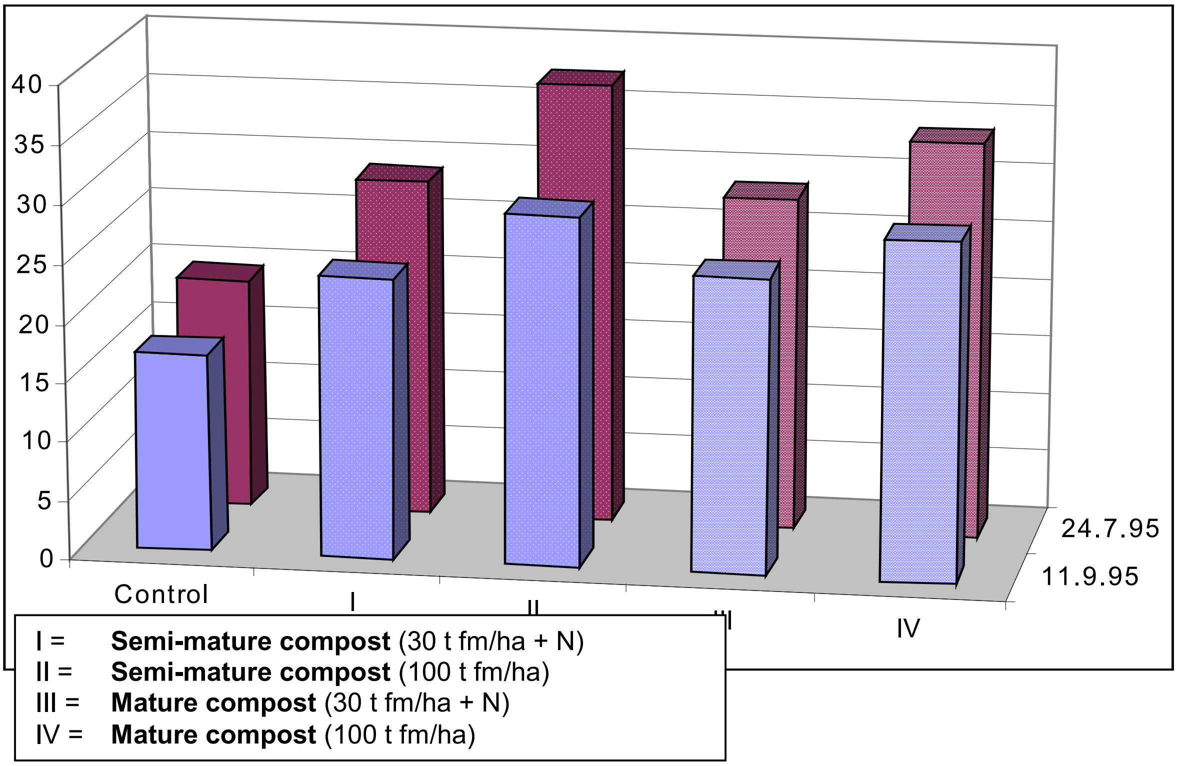


Figure 10: Effect of the use of semi-mature and fully mature compost on soil microbial activity (fluorescein diacetate-hydrolysis) (Petersen and Stoeppler-Zimmer, 1996 in Stoeppler-Zimmer and Petersen, 1997, modified)

8.1.7. Suppression of plant pathogens

High soil humus levels favour saprophytic soil organisms and hence suppress parasitic organisms. Apart from this indirect way of suppressing soil-borne pathogenic organisms, compost can also display direct disease reducing properties. This phenomena can be due to a range of different mechanisms such as a more diverse microflora in the soil, increased competition for carbon resources through higher microbial activity, direct antagonistic activity of certain micro-organisms found in compost, production of antibiotics during the maturation process or even induced systemic resistance in plants (Hoitink and Fahy, 1986; Gattinger et al., 1997; Hoitink 1998a). The suppressive effects of compost towards soil-borne plant pathogens were shown for many pathogen – host interactions; one of them in vineyards. Research in Californian vineyards showed significantly less root rot (11.8 %) in organically managed phylloxerated vineyards than on phylloxerated roots from conventionally managed vineyards (27.1 %) (Porter, 1999). It was said that vineyards seem to be doing fine if they have used compost for at least four or five years.

However, not every compost shows pathogen suppressive properties and to date it can not be predicted at the outset of the composting process whether the mature compost will show more or less suppressive properties. This proves particularly difficult when the compost is produced from a diverse feedstock such as green or bio-waste. This is the reason why, in some cases there is a tendency to amend compost with certain microorganisms which suppress plant pathogens in order to ensure the suppressiveness of compost towards soil-borne plant pathogens (Hoitink, 1998a;

Hauke, 1999). However, at least in the USA the production of these composts is protected through a patent (Hoitink, 1998b).

Nevertheless, if used inappropriately, compost may also have detrimental effects on plant health. It is reported that high soil nitrate levels enhance the incidence of Botrytis (Wagenitz, 1995), which is why the use of large quantities of nitrogen-rich compost may result in an increase of this fungal disease.

Trials were conducted to assess the potential use of compost extracts against a range of leaf diseases on various hosts, including vines, but results were inconclusive.

8.1.8. Yield effects

Through the use of waste derived compost it is possible to maintain soil fertility and to improve soil properties that are important factors for proper plant growth. The sum of these positive aspects associated with the use of compost can be expected to result in the maintenance of yield levels, if not in increased yields in the long-term.

Generally, compost can be classified as a soil improver with nutrient effects. Therefore, direct yield effects can be derived from the use of compost.

To date only few results are available which present grape yields in response to compost use. One such trial was actually designed to evaluate mulch materials (bark, straw, and MSW compost) in a steep vineyard (48 % slope). The results shown in Table 10 demonstrate that there is a distinct benefit in using compost over other mulches and, more importantly that the benefits of compost use really became apparent during the latter half of the 12 year trial period.

In another field trial it was found that the use of MSW/sewage sludge compost resulted in yield increases between 5.6 and 17.5 %, depending on the quantity of compost used.

Table 10: Effect of mulch materials on grape yields in steep vineyards (Fox, 1992 in Stoeppler-Zimmer and Petersen, 1997)

	Average yield 1979 – 1985 (t/ha)	**Average yield 1986 – 1991 (t/ha)**	**Average yield 1979 – 1991 (t/ha)**
Open soil with compost [1)]	8.34	10.86	9.51
Bark [2)]	8.08	7.71	7.91
Straw [2)]	9.04	9.12	9.07
MSW compost [2)]	10.02	12.13	10.99

1) Use as soil improver/nutrient supply, 100 m^3 / ha every three years, no additional nitrogen
2) Use as mulch, bark: 500 m^3/ha in 1979, 600 m^3/ha in 1982, 300 m^3/ha in 1986, additional nitrogen supplied
straw: 8 t/ha in 1979, then annually 6 t/ha, additional nitrogen supplied
MSW compost: 500 m^3/ha in 1979, 700 m^3/ha in 1982, 500 m^3/ha in 1986, no additional nitrogen

However, other results are less conclusive, such as those obtained in compost application trials in a New York State vineyard with MSW and biosolids compost (Peverly, 1992 and 1994). The two composts were compared against an untreated control and the use of nitrogen fertiliser. In the first year all fertilised plots showed higher yields than the unfertilised control with composts and mineral nitrogen showing similar yield levels. Yield variations were greater in the second year and, overall, grape yields from compost amended plots were on a similar level to those from the control plot (unfertilised), except for the high application rate of biosolids compost (Table 11). The increased compost application in the second year was generally not reflected in grape yields.

Table 11: Effect of compost use on grape yields in New York State (figures converted from U.S. Customary Systems units to metric SI units) (Peverly, 1994)

Treatment	**Application rate (t dm/ha for compost, kg/ha for mineral N)**		**Total nitrogen applied (kg/ha)**		**Yield per vine (kg/vine)**	
	1992	1993	1992	1993	1992	1993
Biosolids compost	41.5	60.5	116.8	244.8	7.3	6.7
	83.0	120.5	233.5	489.5	6.0	8.6
MSW compost	48.5	68.0	72.6	157.2	6.5	6.6
	97.5	135.5	144.8	314.4	6.9	5.1
Mineral nitrogen	56.0	56.0	56.0	56.0	6.8	6.5
	112.0	112.0	112.0	112.0	6.9	6.1
Control	0	0	0	0	5.8	6.5

In a trial where the use of bio-waste compost and a commercial organic fertiliser was assessed and compared in two organic vineyards (see Section 7.1.3), Hofmann (1999) recorded the effects of these soil amendments also on grape yield and quality. Table 12 shows these results for the Nierstein and Biebelsheim trial sites.

Table 12: Effect of using bio-waste compost and organic fertiliser on the yield and sugar content of grapes in an organic production system (Hofmann, 1999)

Location		**Nierstein**			**Biebelsheim**		
Variety		**Riesling**			**Mueller-Thurgau**		
	Treatment	**1995**	**1996**	**1997**	**1995***	**1996**	**1997**
Yield (t/ha)	Organic fertiliser	8.40	8.10	22.30		17.60	21.50
	Bio-waste compost	8.15	7.60	21.40		19.00	20.00
	No amendment	8.95	7.60	21.80		18.00	19.00
Sugar content (º Oechsle)	Org. fertiliser	79	82	70		75	77
	Bio-waste compost	78	81	72		75	82
	No amendment	78	82	72		75	79

* No yield measurements in 1995 due to very heterogeneous plots caused by frost damage and severe Botrytis infection

Grape yields varied considerably between the two sites and over time. In 1996 Mueller-Thurgau in Biebelsheim yielded twice as much as Silvaner vines at the Nierstein trial site. In that year compost use in Biebelsheim showed the highest yield, surpassing the organic fertiliser treatment. In 1997 yields in both vineyards were very high, with organic fertiliser showing the best results in both sites. Even though compost yielded slightly less (4 % in 1996, 7 % in 1997), it showed a higher sugar content than grapes grown with organic fertiliser. It is interesting to note that during the three year trial at the Nierstein sites, the use of compost did not result in yield increases over and above what was harvested from unamended vines.

The growth rates of vegetative and generative parts of the vines should be well balanced, particularly with regard to the longer-term effects of organic fertilisers and soil amendments. Hofmann (1999) reports that a ratio of 1:4 between vegetative yield and grape yield is seen as ideal. The Nierstein site showed typical vegetative growth for Riesling, resulting in cuttings of around 2.5 t/year (Table 13). The vegetative development of the vines at Biebelsheim was suppressed during 1995 and 1996 which resulted in very high, sub-optimum ratios of grape *vs.* vegetative yields. In 1997 the vegetative growth improved substantially in the compost and organic fertiliser plots. This demonstrates the beneficial long-term effects of organic amendments, particularly of compost.

Table 13: Effect of using bio-waste compost and organic fertiliser on vegetative growth of vines and the grape:vegetative yield ratio in an organic production system (Hofmann, 1999)

Location		**Nierstein**			**Biebelsheim**		
Variety		**Riesling**			**Mueller-Thurgau**		
	Treatment	**1995**	**1996**	**1997***	**1995****	**1996**	**1997**
Vegetative yield (cuttings) **(t/ha, fm)**	Organic fertiliser	2.65	2.23		1.94	2.23	3.24
	Bio-waste compost	2.85	2.59		1.50	1.86	3.01
	No amend-ment	2.60	2.27		1.82	2.04	2.34
Ratio **(grape yield *vs.* vegetative yield)**	Organic fertiliser	3.17	3.63			7.89	6.63
	Bio-waste compost	2.86	2.93			10.22	6.64
	No amend-ment	3.44	3.35			8.82	8.12

* Vegetative yield not measured in 1997
** No yield measurements in 1995 due to very heterogeneous plots caused by frost damage and severe Botrytis infection

8.1.9. Effects on crop quality

The use of organic amendments in crop production, in particular compost, shows not only positive effects on plant growth but also on crop quality aspects. Field trials with several crops showed that the use of bio-waste compost resulted in crops with a higher level of desirable ingredients (e.g. Vitamin C, trace elements) and a lower level of potentially detrimental components (e.g. nitrate) compared to those grown with chemically compounded fertilisers.

The effect of compost use on the colouring of red wine was investigated in Austria. It was found that the vines, which received compost, not only grew better and were healthier but that they also produced wine whose colour was almost twice as intensive as the conventionally fertilised product (Orthofer, 1982). Phenolic substances that are largely responsible for the taste of wine were also found to be substantially higher in wine produced from grapes grown in compost amended soil. Here, the increase in phenolic substances may be partly attributed to the fact that pomace compost was used which is particularly high in phenolic compounds. However, such phenolic substances are also formed during the composting process of other materials and are, among other mechanisms also responsible for the suppression of pathogens.

Compost use may improve wine quality indirectly by way of improving the soil moisture regime since water stress can reduce the level of amino acids in must (grape juice before fermentation) which may lead to fermentation problems and less aroma in the wine (Wagenitz, 1995).

However, in accordance with results reported from Switzerland (Tamm, 1999), Hofmann (1999) found relatively few discernible differences in the must and wines produced from Riesling grapes harvested from the trial at the Nierstein site (see Sections 7.1.3 and 7.1.8). Musts generated in 1996 showed a considerably higher "Formol reading" for grapes which had received compost or organic fertiliser, compared to those from unamended vines (Table 14). The "Formol reading" (obtained through titration with formalin) is a relative figure that reflects the level of nitrogen (amino acids) contained in the must. Musts which show a "Formol reading" below 14 may encounter serious fermentation problems.

Table 14: Effect of using bio-waste compost and organic fertiliser on some characteristics of must produced from grapes grown at the Nierstein site in 1996 (Hofmann, 1999)

	Organic fertiliser	Bio-waste compost	No amendment
º Oechsle	81	82	82
pH - value	3.0	3.0	3.0
Acids (g/l)*	13.0	13.0	13.8
Formol reading	25	25	20

* Acid was reduced by 3 g/lt. in all treatments

8.2. Potential negative effects of compost use

8.2.1. Oversupply of nitrogen

Typical bio-waste compost contains approximately 1.4 % of nitrogen (N) on a dry matter basis. This results in the supply of approximately 140 kg total nitrogen if 10 t dm of compost are applied per hectare, or 420 kg total nitrogen if 30 t dm are applied every three years, as is often practised by growers. However, only 10 – 15 % of the total nitrogen are plant available during the first year, while the remainder is tied up in organic compounds and will be partly released over time (approximately 40 % of total N in four years). This means that between 42 and 64 kg nitrogen /ha will be available for plant uptake during the first year after compost application (30 t dm). From this perspective it would seem that the amount of nitrogen available from 30 t dm of bio-waste compost is only just able to meet the nitrogen demand for average yields, which ranges between 50 and 80 kg nitrogen/ha per year.

However, the nitrogen release from humus mineralisation needs to be taken into account, also. Depending on the location and soil type, the soil humus content can vary between 0.5 and 3.0 %. Based on a 30 cm topsoil layer, this represents between 24 and 144 tonnes of humus per hectare which, in turn equates to a nitrogen reservoir in the soil of between 1,000 and 6,000 kg. The mineralisation of organically bound nitrogen in the soil depends on the location of the site and its environmental conditions but typically amounts to 2 % per year. This means that between 20 kg/ha per year (0.5 % humus) and 120 kg/ha per year (3 % humus) of nitrogen may be released annually through humus mineralisation.

Consequently, if 30 t dm of compost are applied to a vineyard soil with a humus content of 2 %, it should be expected that between 120 and 140 kg nitrogen/ha will become available for plant uptake, which is considerably more than the (50 to 80 kg N/ha) grape vines require to produce an average crop. This highlights the potential for an oversupply of nitrogen and possible ground water contamination, particularly where large quantities of compost are used or if compost is applied to soils with high humus contents.

To prevent such problems from occurring the voluntary “Eco - Friendly Viticulture” scheme in Rheinland-Pfalz (Germany), limits the introduction of nitrogen from organic sources to 240 kg nitrogen/ha every three years. A similar scheme that operates in the wine-growing region of Franken, permits no more than 150 kg nitrogen/ha to be applied through organic amendments and also prohibits the use of nitrogenous fertilisers during the two years following the application.

However, as seen in Section 8.1.3 field trials yielded conflicting results as far as the release of nitrogen from compost is concerned. These varying levels of nitrogen release from compost can be due to a range of factors, one being the type and quality of the compost used.

A trial in an organic horticultural cropping situation demonstrated to what extend the release of nitrogen can vary with different composts (Figure 11). Both semi-mature and mature compost was applied in autumn at a rate of 100 t/ha and the nitrate level (NO_3) measured during the two following winter periods, when nitrate leaching is most likely to occur. It is clear that the nutrient loading of the mature compost was considerably higher than that of the semi-mature compost but it also became apparent that the nitrogen and mineralisation dynamic of the two composts were distinctly different. The site where the semi-mature compost was applied showed hardly any difference to the control site.

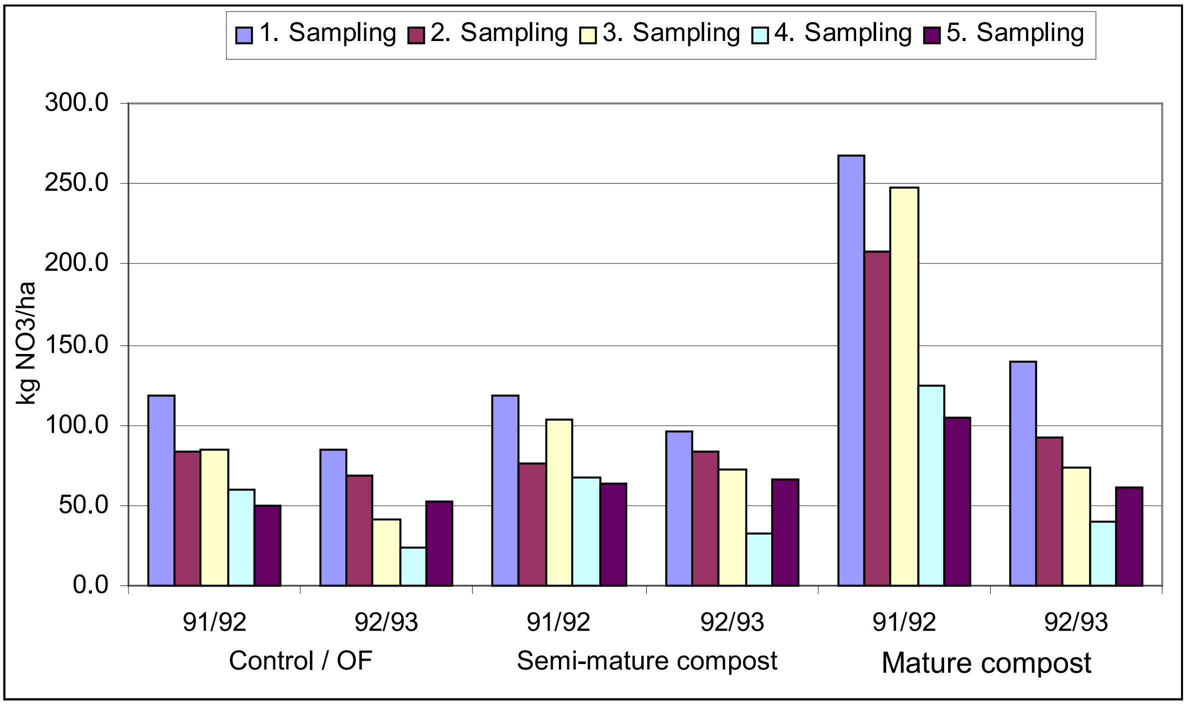


Figure 11: Development of nitrate contents in soil (0 – 90 cm) amended with mature and immature compost during two winter periods (Petersen and Steoppler-Zimmer, 1996 in Stoeppler-Zimmer and Petersen, 1997) (identical to Figure 4)

8.2.2. Phosphorus

Generally the use of compost may cause a problem where previous or parallel fertilisation regimes resulted in high levels of individual nutrients in the soil. Phosphorus levels in vineyard soils may restrict the use of compost. The assessment of some 3,500 vineyard soil samples revealed that virtually all soils in the assessed regions in two German States showed an oversupply of phosphorus. Subsequently, in 86 % of cases, it was recommended not to apply any more phosphorus. According to the “Eco - Friendly Viticulture” guidelines (Rheinland-Pfalz), no phosphorus-rich organic materials should be applied if the soil (0 – 60 cm) shows a content of more than 39 mg P_2O_5 / 100 g.

8.2.3. Potassium

Some composts can show high potassium levels and there are conflicting results about the effect of potassium on wine quality. However, organically grown grapes showed lower potassium levels than conventional ones, even though the soils showed similar potassium contents and no potassium was applied during the trial (Wagenitz, 1995). The difference was attributed to different soil management practises and the resulting difference in soil water status and water uptake by vines.

The ratio between potassium and magnesium in the soil should not exceed 3:1 since the two nutrients may compete for plant uptake (Wagenitz, 1995).

8.2.4. Impurities

Both the physical and chemical contamination of compost derived from waste products fundamentally depends on the quality of the waste materials processed. Impurities can be extracted manually or mechanically to a certain degree but there will always be residual glass or plastic pieces if the input material is of low quality. For green waste, Wagenitz (1996) saw the non-biodegradable impurities much more of a problem than heavy metals.

Some organic growers (Bernhard, 1999; Koepfer, 1999) expressed concern over the low quality of commercially available compost. This was particularly with regard to the level of impurities and odour problems they experienced with compost from large-scale, fully enclosed composting plants.

8.2.5. Heavy metals

In highly industrialised countries all composts contain a certain level of heavy metals and compost quality standards or regulations govern permissible heavy metal contents in compost in many countries (see Section 5). Organic farmers and their organisations are more cautious about the potential hazards external farm inputs may hold and the German umbrella organisation for organic farming (AGOEL) has established guidelines for heavy metal contents in compost which amount to exactly 50 % of the widely used Bundesgűtegemeinschaft (BGK) standards.

However, in order to effectively protect the soil, plants, animals and humans, regulations need to specify not only heavy metal limits in compost but also maximum heavy metal loads that may be applied through the use of compost and other organic amendments. Schwab (1996a) points out that in some cases compost application at a level that is recommended in Bavaria (7.5 t dm/ha per year or 22.5 t dm/ha once in 3 years) may result in the violation of existing limits for heavy metal loading, specifically in the case of copper.

However, heavy metal inputs are not confined to compost alone. Schwab (1996b) calculated that the use of bark as a mulch material may also violate the above mentioned loading limits if more than 200 m^3/ha is used. With bark, cadmium levels are a particular problem and he recommends that bark should not be used for mulching if it contains more than 0.7 mg cadmium/kg. Wagenitz (1996) states that as much as 3 kg/ha per year of copper may be introduced into a vineyard through plant protection measures at the current permissible rate. In contrast, he points out that only approximately 400 g/ha per year is introduced through the use of compost if 30 tonnes of compost (60 mg Cu/kg) are applied over a three-year period. Likewise, 2 – 3 kg zinc/ha is introduced into the soil from wires in the vineyard while 30 tonnes of compost (200 mg Zn/kg) add approximately 1.3 kg zinc/ha.

Effective protection against detrimental environmental effects caused by heavy metals (by compost and other soil inputs) should include maximum limits for

- the compost,
- the amount of heavy metals that can be applied annually (loading) and
- the maximum heavy metal content in the soil.

This approach is standard procedure in sewage sludge regulations and was adopted in Germany by State (Komposterlass Baden Wuerttemberg, 1995) as well as Federal compost regulations (Komposterlass der Bundesregierung, 1998). In this respect, copper is a particular problem in many vineyards, particularly old ones due to the long-standing use of copper as a plant protection agent. Schwab (1996a) reports that many vineyard soils exceed the 60 mg copper/kg limit established in the Baden-Wűrttemberg compost regulation. The same limit was later adopted in the Federal compost regulations.

However, heavy metals contained in compost are considerably better bound than those in mineral or organic fertilisers and are therefore less available for plant uptake. This is demonstrated in Table 15 that shows the heavy metal contents in the soil and produce after fertilisation with compost and mineral fertilisers.

The availability of heavy metals for plant uptake is governed largely by the pH value of the soil. Solubility and plant availability of heavy metals decreases with increasing pH values. Due to its alkaline reaction and the fact that compost adsorbs heavy metals, compost use aids the immobilisation of heavy metals.

Table 15: Effect of various fertilisers on the cadmium, nickel and zinc content (mg/kg dm) in the soil and produce (cabbage) (Fuchshofen et al., 1993 in Stoeppler-Zimmer and Petersen, 1997)

	Cadmium		**Nickel**		**Zinc**	
	Soil	**Cabbage**	**Soil**	**Cabbage**	**Soil**	**Cabbage**
Unfertilised control	0.18	0.018	14	0.25	50	11.9
NPK (180/125/300) [1)]	0.22	0.035	14	0.33	49	17.5
Bio-waste compost (120 t dm) [2)]	0.24	0.018	15	0.21	50	11.3
Composted manure (65 t dm) [2)]	0.22	0.018	13	0.27	54	10.7

1) = Mineral fertiliser for cabbage
2) = Total compost applied during previous 6 years

However, grapevines take up very little heavy metals and very little is deposited in the grapes (Table 16), especially not at low pH levels. In addition, the filtration processes during wine production extract most heavy metals which may be found in the must (Mohr, 1987). Therefore, the previous practice of using MSW compost in vineyards did not pose a potential danger for wine drinkers. However, high concentrations of heavy metals in the soil may have detrimental effects on root growth and microbial activity, as is documented for example for copper in vineyards (Mohr, 1987).

Table 16: Heavy metal content (mg/l) in must after heavy application of co-composted MSW and sewage sludge (Mohr, 1985 in Stoeppler-Zimmer and Petersen, 1997)

Location, Date	**Zinc**	**Copper**	**Lead**	**Cadmium**
Baden, 29.9.1980				
Control	0.61	2.10	0.041	0.0011
900 t/ha compost	0.68	2.40	0.049	0.0014
Bernkastel, 8.10.1980				
Control	1.10	0.35	0.067	0.0011
300 t/ha compost	0.71	0.32	0.066	0.0009
600 t/ha compost	1.20	0.32	0.063	0.0011
Kues, 8.10.1980				
Control	0.60	0.29	0.055	0.00085
300 t/ha compost	0.30	0.32	0.045	0.00064
600 t/ha compost	0.44	0.34	0.048	0.00043

9. Recommendations for the use of compost in Germany

Due to the relatively low nutrient demand of vines the nitrogen application through organic fertilisers and soil amendments is limited to 150 kg/ha during a three-year period according to the guidelines for integrated vineyard management in Germany.

In 1992 the German Federal Association for Compost Quality (Bundesgűtegemeinschaft Kompost - BGK) produced a 25 page booklet about compost use in viticulture and fruit growing. Apart from describing the beneficial and potentially detrimental effects and the quality assurance scheme of the organisation, the brochure also contains recommendations for the use of compost for various viticulture applications. These recommendations are summarised in Table 17.

Table 17: Recommended use of compost in viticulture (Bundesgűtegemeinschaft Kompost Region Sűdwest, 1992)

Use / Soil type	Quantity
Vineyard establishment – low nutrient, mature compost	
Degraded or disturbed soils	
- medium / heavy soils	100 – 150 m^3/ha (once)
- light / medium soils	75 – 120 m^3/ha (once)
Soils with a low humus level (< 2 %)	
- medium / heavy soils	75 – 120 m^3/ha (sufficient for 2 – 4 years)
- light / medium soils	50 – 100 m^3/ha (sufficient for 2 – 3 years)
Soils with a high humus level (> 2 %)	
- medium / heavy soils	50 – 100 m^3/ha (sufficient for 2 – 4 years)
- light / medium soils	50 – 75 m^3/ha (sufficient for 2 – 3 years)
Regular use – mature or semi-mature compost	
Every year	25 m^3/ha
Every second year	50 m^3/ha
Every third year	75 m^3/ha
Every fourth year	100 m^3/ha
As mulch and for erosion control –coarse compost (10 – 30 mm) with low nutrient status	
Every 3 – 4 years	300 – 500 m^3/ha (under the vines)

Note: 25 m^3 = 16 t fm = 10 t dm (assumed bulk density of 0.65 t/m^3 and water content of 40 %)

If deep ripping and intensive cultivation precedes the establishment of vineyards only low nutrient compost should be used since soil cultivation will result in a substantial flush of nitrogen due to increased mineralisation rates. If the compost is incorporated to a depth of more than 5 cm it needs to be ensured that the material is fully matured. Less compost should be used on lighter soils and soils with a high humus content to reduce the risk of nitrogen leaching.

If supplied in the planting hole, compost can greatly facilitate the establishment of young vines through enhanced nutrient supply and water storage. However, the compost needs to be mixed with soil to prevent detrimental effects due to potentially high nutrient and salt levels. For this application high-nutrient compost should be mixed at a ratio of 1:4 – 1:6 with soil and compost with a lower salt content can be mixed at a ratio of 1:2 – 1:4.

Regular compost applications for nutrient supply and soil improvement should be based on soil nutrient and humus levels and the use of compost needs to be reduced if nutrient and humus levels are high. On average vineyard soils, approximately 25 m^3/ha of compost should be delivered annually, which is equivalent to the legal limit of 10 t dm/ha per year. Due to high application costs compost is often applied at higher rates every third or fourth year. It is recommended that only fully matured, non-odorous compost be used between flowering and harvesting. However, in general compost should be applied in late autumn, winter, or early spring on frozen or dry ground.

Compost can also be used to establish inter-row cover crops. In that case the BGK booklet recommends using 60 – 100 m^3/ha of fine (0 – 20 mm) compost that can have a relatively high nutrient density.

If compost is used as a mulch or to control erosion, it is recommended to use 200 – 300 m^3/ha of either coarse (10 – 30 mm) compost with a low nutrient content or semi-mature, pasteurised compost. The compost should be applied under the vines to a maximum depth of 5 cm in a band not wider than 0.5 m.

10. Economic aspects of compost use

For growers the total costs of using compost comprise purchase, transport and application costs. One commercial compost producer in Germany who supplies large quantities of compost to vineyards charges DM 8 / t + VAT ($ 6.66 / t[1]). This price includes loading but not transport. If the latter is included, costs increase to approximately DM 16.50 – DM 21.40 per tonne ($ 13.75 – 17.83 / t). In steep vineyards where tractor access is not possible the total costs of using compost may increase to as much as DM 113 – DM 125 per tonne ($ 94.17 – $ 104.17 / t). Even in more favourable vineyard locations the costs of using compost are relatively high. Growers, however, tend to apply the compost in a time when there is less other work to be done and as long as no new equipment has to be purchased there is a tendency among growers to only account for the variable costs and not the total costs. However, it is reported that application costs could be reduced considerably by organising the spreading of compost on a wider scale (contractors, co-operative approach among farmers or with the compost producer).

[1] $ 1.00 = DM 1.20

11. Organic wine growing

For philosophical and a wide range of practical reasons the use of compost is very attractive to organic wine production. Therefore, as in other industries (Biala, 1999) the use of green waste and bio-waste compost in viticulture was pioneered to some degree by organic growers and their organisations. Two of the reports that provided the most comprehensive information for this literature review were specifically prepared with respect to organic viticulture (Hofmann, 1998; Stoeppler-Zimmer and Petersen, 1997).

Last year France reported an increase of 30 % in organically managed vineyards to reach a total area of 7,550 ha (Roussou, 1999). Fueloep (1999) reported of 300 organic ha in Hungary, Rumbos (1999) of 1,307 ha in Greece, Stoeppler-Zimmer and Petersen (1997) of 1,500 ha in Germany and Gubler (1999) of some 30,000 ha in California. Apart from California where, according to Gubler's figures organic wine production accounts for almost 10 % of the total area under vines, the area of organically grown vines is still very small compared to the overall area of vineyards at a level of probably 1 – 3 %.

Nevertheless, organic viticulture and with it the use of compost in grape production has generated a considerable amount of interest over the last few years and in Germany many of the State Viticulture Research and Education Institutes either operate organic vineyards or conduct organic viticulture trials.

However, due to Europe-wide regulations which prohibit the use or importation of genetically modified organisms or its derivatives to organic farms it seems likely that from the end of this year organic farmers and growers will not be able to utilise compost derived from kerbside collected food and garden waste since the input materials for the composting process can not be guaranteed to be free of genetically modified products. The use of green waste compost on organic farms on the other hand will still be permissible.

12. Current and future research activities

As mentioned elsewhere in the report there was little information available on the use of composted organic waste materials in viticulture apart from German sources. However, in many of the other surveyed countries work is under way to assess the use of organic waste materials in grape production, either as mulch or as a soil amendment and nutrient source. This was noted particularly for Italy, New Zealand and South Africa.

In Germany several research projects which assess a range of different effects of compost use in grape production are under way. At the moment researchers are mainly interested in the level of nitrogen mineralisation after the use of compost and other organic amendments. This interest stems from both a plant nutrition point of view as well as from an environmental point of view which seeks to prevent or minimise nitrate leaching. Since research to date has yielded inconsistent results (see Section 7.1.3) it was decided to embark on a long-term collaborative research project which investigates this issue. In 1999 a ten-year research project was initiated which involves six State Viticulture Research and Education Centres in the testing of compost use in grape production. Compost from the same source will be applied to eight trial sites in quantities of 30 – 50 t dm/ha every 2 or 3 years. During the 9 – 10 year trial, researchers will assess mainly nitrogen dynamics and its release, the development of humus levels and the fate of heavy metals.

It is striking that most of the current research projects that assess the effects of compost use in viticulture are long-term, running for 5 – 10 years or even longer. This is demonstrated by work in this area currently funded by the Bavarian Ministry for Food, Agriculture and Forestry (Table 18).

Table 18: Current research projects involving the beneficial use of organic waste materials in viticulture which are funded by the Bavarian Ministry for Food, Agriculture and Forestry (as of 11/1999)

Assessment of integrated and organic viticulture systems	
Duration	1995 - 2009
Objectives	1. Assessment of the performance of Vitis vinifera cultivar `Domina´ in an integrated and organic production system. 2. Evaluation of the abundance of soil macro- and microorganisms in different production systems. 3. Investigation of the effects of different cultivation methods on soil fertility and nutrient dynamics.
The effect of different cover crop management and fertilisation schemes on the quantitative and qualitative performance of grape vines and on nitrate leaching	
Duration	1996 - 2009
Objectives	1. Optimising grapevine nutrition in water stress situations by means of cover crop management. 2. Assessment of the effect of different cover crop management and fertilisation schemes on the quantitative and qualitative performance

	of Vitis vinifera cultivar `Blauer Portugieser´ and on nitrate leaching
Assessment of different cover crops and ways of managing them, with and without additional fertilisation in newly established organic vineyards	
Duration	1996 - 2009
Objectives	1. Assessment of different cover crops and the use of additional organic fertilisers on the quantitative and qualitative performance of Vitis vinifera cultivar `Müller-Thurgau´. 2. Assessment of the effects of different cultivation methods on the soil nitrate dynamics and nitrate leaching
The effect of various organic fertilisers on certain soil characteristics and the yield levels of grapevines	
Duration	1993 - 2003
Objectives	1. Assessment of the effects of various organic fertilisers on soil nitrate and humus levels and other soil characteristics. 2. Assessment of the effects of various organic fertilisers on vegetative and generative growth characteristics of grapevines
The effect of permanent cover crops, different supplies of humus and over-head irrigation on the nutrient status of the soil and the grapevine	
Duration	1991 - 2000
Objectives	Assessment of the effects of permanent cover crops (established at different ages of the vineyard), various organic fertilisers and irrigation on the availability of nutrients, the soil humus content and the yield of grapevines (vegetative matter and grapes).
A comparison of different reduced input grape production systems with special reference to quality aspects	
Duration	1990 - 1998
Objectives	1. Assessment of various low-input grape production systems with regard to the sustainability of yield and quality of Vitis vinifera cultivars. 2. Investigation of nutrient-dynamics, labour requirements and costs associated with the various production systems. 3. This trial will concentrate on “environmentally friendly” viticulture
The beneficial use of compost and other organic waste products in agriculture	
Duration	1992 - 2004
Objectives	Organic waste products are to be used increasingly as soil amendment and a source of nutrients for agricultural plant production. This requires low levels of contaminants and impurities and a good knowledge of the nutrient levels contained in the materials and their effects. Composted and uncomposted materials will be trialled. The project also aims to establish agronomic and environmental guidelines for the use of composted and uncomposted waste products.

These long-term compost application trials reflect the understanding that compost use may show its full potential only after prolonged use and only once the soil eco-system has changed sufficiently due to the use of compost. The long period of time required to change the soil eco-system is well documented from vineyards which convert to organic farming practices. An organic vineyard operated by the Weinsberg State Research and Education Centre for Viticulture reported six years after converting to organic viticulture that the new system is „more or less“ stable (Landwirtschaftsministerium Baden-Wuerttemberg, 2000). In a recent seminar in Melbourne, which was conducted under the auspices of this project, Dr. Hofmann demonstrated the poor state typical vineyard soils are often in (Plate 1, Appendix) and that in order to rectify the fundamental problem the entire soil eco-system needs to be improved (Biala, 2000). However, he also stressed and showed that compost in combination with cover crops can play a major role in achieving this vital goal.

13. Experience with the use of compost in Australia

The idea of composting and utilising organic waste materials is not new to Australia as is shown by major conferences (e.g. COMPOST 94 in Brisbane) and studies on the processing and marketing of green organics in Victoria (Recycling & Resource Recovery Council, 1993 and 1994) dating back to the early 1990's. Consequently, as recycled organic materials became more readily available and the marketing and use of such products became an area of interest, compost application trials were established in a range of different industries to assess the potential benefits of compost use. A compilation of all growth trials in Australia that involve the use of compost in one form or another shows that work in this field is well under way. The February 1999 summary (Tables 19 and 20) reveals that compost application trials conducted until early 1999 used recycled organic materials mainly as a mulch in fruit and wine growing and to a lesser degree as a soil amendment and nutrient source in horticultural and agricultural production systems. It also becomes apparent that all trials were conducted either in NSW, Victoria, South Australia or Western Australia, States in which sufficient landfill levy funds are available to fund market development activities for recycled organic materials (ROM) such as growth and demonstration trials. In Tasmania and Queensland no such funds are available and until recently no compost application trials were established (or reported) in these States. However, more compost application trials are established around Australia, some of them supported through Environment Australia's Natural Heritage Trust funding.

The compost application trials in vegetable production covered in the 1999 survey did not yield consistently positive results (Table 20). More research in this field is warranted and under way. In contrast, all trials where ROM were used as mulch showed positive effects for all parameter assessed, except for yield in cherries and growth response in oranges where results were either inconclusive or unaffected by compost use (Table 19).

The use and assessment of ROM in Australian viticulture was pioneered in South Australia where Buckerfield and Webster (1998, 1999) reported large benefits from the use of composted green organics as mulch. Apart from improved development and growth of vines, they reported yield increases of up to 300 % through the use of ROM. This was mainly due to an increased bunch number per vine where the vines were mulched. Under these conditions the soil moisture content was substantially increased, resulting in a higher survival rate of grape bunches.

In contrast, Wilkinson et al. (2000) were not able to report similar yield increases from trials in Victoria even though the mulching of vines with ROM increased soil moisture levels in a similar way as was observed in South Australia. However, they suggest that vines in the cooler Victorian wine growing areas (Yarra Valley, Mornington Peninsula) are unlikely to experience water shortage to the same extend as in South Australia. This is seen as the reason why ROM mulch is unlikely to show as spectacular results in Victoria as was shown in South Australia.

The current nation-wide compost application trial should provide further information with regard to the effects of using ROM in different environmental conditions (climate, soil type, grape variety). Subsequently this should results in the development of recommendations for the use of ROM products in the various Australian wine growing regions. It should be ensured that the full potential benefits of ROM products will be made available to users, for example by taking the nutrient release from these products into account when establishing a nutrient budget, possibly resulting in reduced fertiliser inputs for growers. This approach should result in tailor-made ROM products, meeting the specific needs of the viticulture industry.

Table 19: Growth trials in Australia where compost was used as mulch (as of Feb. 1999)

	Crop	Parameter	Effects	Comments
Fruit Trees	Almonds (SA)	Vigour of young trees Weed control	+ +	25 weeks after application
	Apples (NSW)	Soil moisture	+	5 year old trees
	Apples (NSW)	Survival rate Increased tree height	+ +	Replanting of apples; mulching in conjunction with compost application before planting
	Avocados (WA)	Increase in growth (trunk)	+	Establishment of trees
	Cherries (SA)	Soil moisture Berry size Cherry yield Value of harvest	+ + + +	0 – 10 cm depth
	Cherries (Vic)	Weed suppression Cherry yield	+ +/-	
	Oranges (SA)	Soil moisture Leaf-greenness Increase in growth Average fruit weight	+ + +/- +	At surface level, 5, 10 cm deep 6 weeks after application 6 weeks after application 30 weeks after application
	Oranges (WA)	Increase in growth Increase in growth (trunk)	+ +/-	One year old trees Five year old trees 12 months after application
	Peach (NSW)	Soil moisture	+	Fruit did not ripen around calyx
	Pears (SA)	Shoot extension Increase in trunk diameter Soil moisture Yield	+ + + +	90 days after application 120 days after application
Vineyards	Vines (SA)	Soil moisture Increase in shoot length Increase in shoot length Bunch number Average grape weight Grape yield / vine Juice sugar content	+ + + + + + +	Established vines Established vines Young vines / 5 months mulched dto. dto. dto. dto.
	Vines (Vic)	Soil moisture Weed suppression	+ +	Young and established vines
Roadside Trees	Eight species of native trees (NSW)	Survival rate Increase in tree height Increase in canopy width Increase in trunk diameter	+ + + +	
Roadside Shrubs	Acacia and Callistemon spp. (Vic)	Survival rate Increase in plant height Weed suppression	+ + +	
Cut Flowers	Chrysanthem ums (NSW)	Weed suppression	+	

Table 20: Growth trials in Australia where compost was used as soil amendment and organic fertiliser (as of Feb. 1999)

	Crop	**Parameter**	**Effects**	**Comments**
Vegetables	Cabbage (NSW)	Cabbage heart weight Marketable produce Heavy metal content	+ +/- +/-	2 cm compost (= 200 m^3/ha) incorporated into 60 cm soil
	Carrots (WA)	Foliage colour and development Total yield	- +/-	25, 50, 100, 200 dry tonnes / ha Negative effects at high application rates
	Cauliflower (WA)	Total yield Marketable produce	+ +/-	0,15, 30, 60 dry tonnes / ha Yield decreased slightly with high applications
	Tomatoes (NSW)	Hydraulic conductivity Soil aeration (bulk density)	+ +	Demonstration trial, not replicated 4 cm compost (= 400 m^3/ha) applied
Disease suppression	Cauliflower - Suppression of club root (NSW)	Plant establishment Increase in plant weight Marketable produce Heavy metal content	+ *(2,4cm)* + + +/-	1, 2 and 4 cm compost (=45, 90 and 180 dry tonnes/ha) incorporated into 10 cm soil Marketable produce equal to third best commercial treatment

14. Conclusions

This review of the international literature showed that a considerable body of information is available on the various effects compost use has on soil properties and plant growth but it showed also that considerably less knowledge was gathered about the use of compost in grape production. In many countries research and pilot projects which investigate the use of composted waste materials in viticulture are only just beginning and in many cases seem not much more advanced than in Australia, if at all.

Exceptions to this seem to be California and Germany where considerable amounts of compost are used in vineyards. However, very little valuable information was obtainable from the USA which is why results presented in this report reflect predominantly research that was conducted in Europe (Germany).

There is sufficient evidence to show that the use of compost results in a wide range of positive effects related to the physical, chemical and biological soil properties, many of which are closely associated with a high soil fertility status. These effects however were not always transformed directly into a yield response and there was very little discernible difference in must or wine quality.

Compost is a soil improvement agent that normally provides all essential macro- and micro nutrients for plant production purposes, except for nitrogen. Since nitrogen plays such an important role in plant growth and yield development, researchers focused much attention on the availability of nitrogen in different types of compost and on the release of nitrogen through the mineralisation of organic matter over time. Presented results show largely conflicting responses to the use of compost in vineyard soils, which range from nitrogen draw down to a nitrate flush equivalent to 250 kg NO_3/ha. Apart from nitrogen being an important plant growth factor it also can cause adverse environmental effects if more is present in the soil than plants can absorb and utilise. The same is true for phosphorus even so it is a lot less mobile than nitrate. Nevertheless it still can be transported into surface waters through erosion and phosphorus is largely responsible for the eutrophication of surface waters and algal blooms. Since grapevines have relatively little nutrient requirements, the oversupply of nutrients, particularly nitrogen and phosphorus may cause environmental problems if large quantities of compost are applied, for example as mulch. However, on the other hand with many Australian soils inherently low in phosphorus and various trace elements, compost may be able to redress a range of nutrient deficiency related plant production problems if used appropriately.

It can be assumed that, generally, conventionally farmed vineyard soils are relatively degraded with a low organic matter content and little microbial activity. Therefore, initially the applied compost may not be readily degraded or incorporated into the soil food web and not much more than physical effects may be observed. However, the use of compost provides an excellent means of altering the entire soil ecosystem and to improve its soil fertility status. Only once this goal has been reached can compost be expected to show its full potential. Normally this stage should be reached after 3 to 5 years of compost use.

Many research and funding bodies in Europe face up to this fact by running and initiating long-term research projects which extend over periods of 5 – 10 years. Only such long term projects make it possible to predict with any accuracy the effects of compost use on the soil ecosystem, since both the compost and the soil it is applied to represent biological systems which are governed by a wide range of internal and external factors and which can vary greatly from year to year, from site to site or from compost to compost.

Based on the findings of this literature review it is recommended that, with regard to future Australian research activities related to the use of compost in viticulture and other industries, the following objectives be included:

1. Investigate the mineralisation and release of nitrogen from compost under various environmental conditions

2. Investigate the potential of compost to redress phosphorus and trace element deficiencies

3. Investigate the potential detrimental environmental effects of high compost applications

4. Develop recommendations for the appropriate use of compost for various industries

5. Investigate the long-term effects of compost use.

6. Generally it is recommended that compost application trials be conducted for a minimum of 3 to 5 years, ideally even longer.

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A P P E N D I X


Plate 1: Left: Typical compacted vineyard soil with low organic matter content, little root penetration and low microbial activity
Right: Soil from organic vineyard which uses cover crops and compost as management tools
(Photographs courtesy of Dr. U. Hofmann)

Institutions and individuals approached in the search for information about the use of compost in viticulture and their response

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