Compost use in premium vineyard development

Alfred Cass
Alfred Cass & Associates
2330 Mark West Springs Road
Santa Rosa, CA 95404, USA.
AlfredCass@WineSoil.com

Daniel Roberts
Integrated Wine Growing
269 Virginia Avenue
Sebastopol, CA 95472.
daniel@integratedwinegrowing.com

Summary

Compost, of some type or another, is often applied to soil during vineyard development and after planting, during management of the vineyard. However, the reasons for applying compost may not always be clear to the user and the possible negative effects that might result are often not appreciated. There have been several very good reviews of compost use in recent years (eg. Biala, 2000 and Wilkinson, 2001). The purpose of this article is not to repeat the ideas conveyed in these publications but to focus attention on the particular benefit from using compost in establishing new vineyards and to compliment and reinforce the ideas of Robinson (2001).

Introduction

Because use of compost is generally only effective if large amounts are applied (at least 10 metric tonne/ha), any toxic or undesirable constituents in the compost can have a serious effect on the success of vine survival and growth. So, the type and quality of the compost needs to be carefully matched to the purpose of applying it. We list, in Table 1, those factors of compost quality that we have found to be essential in judging the suitability of compost as a soil amendment in premium vineyard development worldwide.

Compost is sometimes used as a fertiliser. However, premium wine grape production requires precise fertiliser application that is carefully timed and located. This means that the use of compost in premium vineyards as a fertiliser will not usually be successful because of the variability of nutrient concentrations in compost and the difficulty in applying sufficient individual nutrients in balanced proportions. Consequently we recommend selecting only those composts for structure remediation that have low plant nutrient concentrations, ie. high C:N ratios.

Sometimes growers wish to apply surface mulch to soil to conserve water, control weeds and provide nutrients. Surface-applied compost can provide these benefits but the expense of applying enough compost to achieve these aims generally favours use of cheaper materials such as cereal straw. Consequently, we do not advocate compost application as mulch but always incorporate the compost as deeply as possible by disking.

There is one clear and indisputable benefit to be derived from using compost in vineyard development, especially if the developer whishes to produce premium quality fruit. Application of sufficient amounts (10 tonne/ha or more) of compost to restore the physical and biological destruction wrought by the development process will have measurable and lasting benefits on vine survival, growth and future berry quality. Cass and McGrath (2005) have provided substantial evidence, drawn from the scientific literature, to support this assertion. So, the purpose of this article is to draw attention to the importance of assessing the composition of compost before application and to provide criteria for judging the acceptability of the compost.

Effect of site preparation on soil quality

Land development for vineyards and, to a lesser extent, ongoing management of vineyards, involves intensive tillage and high traffic that can progressively destroy favourable soil structure. Soil aggregates are fractured and crushed at the soil surface and deeper, down to the lowest depth of tillage. Soil porosity is reduced by compaction under the wheels of heavy tractors and below the cutting edges of tillage implements. Soil organic matter, exposed by tillage, is lost by oxidation and soil aggregates become more susceptible to slaking and dispersion. This initiates a cycle of further deterioration to soil physical properties by crusting, hard-setting and saturation.

Soil physical properties affect many of the biological processes that create humus from organic matter. Poor soil structure retards soil biological activity and normal cycles of organic matter turnover are slowed. A decline in the quality of secondary physical properties occurs in response to this: harder soil, less infiltration of rain and irrigation water, poorer drainage, etc. These physical changes affect the biological activity of the soil, reducing root growth and microbial activity. Regeneration of organic matter in soil is retarded, accelerating the downward spiral of soil physical quality.

Benefits from compost application

Soil structural constraints often limit vine growth, although this may not be widely appreciated and, more commonly, solutions are not often obvious. Adding compost to soil is one of the most commonly used rehabilitation practices to improve soil physical properties. The work of Biala (2000) and Wilkinson (2001) shows that this is a well established practice in agricultural industries worldwide. Compost provides the raw material to stimulate microbial activity which produces secondary compounds that act as binding substances to stabilise soil fragments created by tillage. In addition, compost stimulates biological activity and increased macro-faunal activity and root growth create additional porosity. Applying compost to the soil surface as mulch may have some benefits for moisture conservation and weed control that can improve soil structure. However, full benefits of compost probably cannot be realised unless the compost is mixed with soil.

Effective tillage creates large pores (tillage voids). Appropriate tillage coupled with addition of compost to the soil can restore favourable structure and boost organic matter level, counteracting the downward spiral of decreasing soil organic matter and establishing conditions for a more viable micro-faunal population. Compost is effective in stabilising pore structure created by tillage and, indirectly, in creating new pore structure by stimulating biological activity. The physical and biological response to compost addition depends on the effectiveness of tillage in creating new pores, the effect of the compost in stabilising the newly created porosity and the management practices that are established to avoid systematic destruction of the newly created pore structure.

Incorporating compost by careful tillage has been shown to produce long-lasting improvements to total porosity. In particular, the stimulation of biological activity by compost addition is an important first step in creating a heterogeneous pore size distribution with its positive effects on soil biology, hydrology, aeration, and mechanical condition. Compost provides substrate for a variety of soil fauna, as for example, earthworms, with capacity to create pores of different sizes. Enhanced biological activity stimulates root growth. Tap and nodal root growth, particularly in grasses, create large pores (0.075 to 0.5mm diameter), which are important for soil aeration, hydrology and friability.

Soil water storage capacity is enhanced by a high proportion of small and medium pores (0.0005 to 0.075mm diameter). These pore sizes correspond to the diameter of grass lateral and seminal roots. Stimulation of microbial activity in soil and the increase in the quality of the root environment obtained by addition of compost has the capacity to increase these water storage pores. Many reports show that water retention capacity of soils with high porosity is usually higher than in soils with low porosity. Compost and compost residues themselves have some water storage capacity but this contribution is small in relation to the capacity of soil pores. However, stimulation of favourable biological activity by compost addition is an important component for creating favourable root growth conditions.

After tillage, especially if tilled at the Lower Plastic Limit (Cass *et al.* 2003), soil generally has a large proportion of large pores (tillage voids) that are unstable. Any disturbance, especially wetting or heavy traffic will cause these pores to collapse, especially at the surface. However, if the soil has been treated with compost prior to tillage, a larger proportion of these pores will persist through successive wetting and drying cycles. Soils with a large proportion of macro-pores generally have higher infiltration rates and higher saturated hydraulic conductivity values. Without addition of compost, the infiltration rate and hydraulic conductivity of most tilled soils may decline to levels even lower than those present before tillage.

Compost addition has little impact on the physical properties of subsoils, even if tillage has penetrated to the subsoil, because of the difficulty of incorporating compost to this depth and the low microbiological activity. Generally direct benefits from compost are confined to the depth of incorporation, which is the depth to which the compost can be mixed with soil by disking or other vigourous tillage.

How much compost should be applied?

An important question is how much compost should be applied to soil to achieve a particular result and at what intervals. There are many studies (Cass and McGrath, 2004) that show linear positive responses to compost addition up to practical levels of about 5% of the soil volume (100tonne/ha if incorporated to a depth of 200mm). However, compost composition varies and to some extent, the amount of compost that might be applied depends on the composition of the compost. This is particularly true for regularly repeated applications of compost. Generally, in production of premium quality grapes, repeated application of compost is not required because, after development of the vineyard, stable soil structure is maintained by permanent cover cropping where soil disturbance is minimised and nutrients are supplied via other means. Benefits from compost are generally only realised when used in conjunction with tillage.

Application of large amounts of compost can have adverse effects. For example, too much nutrient may be added with the compost, particularly nitrogen, and vine growth may subsequently be too vigourous. Often the salt load in compost is high and application of excessive amounts of compost can induce high salinity in the amended soil. Determining the optimum rate of compost to apply to vineyard soils as a conditioner will depend on site-specific factors:

- moisture regime
- soil type
- plant type.

In many cases the upper limit of application may depend on the quality of the compost.

Compost quality factors

Table 1, reproduced from Cass and McGrath (2005), is a compendium of practical criteria derived from Anonymous (2001), Standards Australia (1997), Thompson (2001) and Wilkinson (2001) that can be practically applied using relatively inexpensive assay methods, to judge the quality of compost for restoring and promoting favourable soil physical and biological properties. Because the composition of compost is generally not under the control of the user, the material should be subjected to assay before being used. Various protocols for assaying compost have been published or are in the process of publication by a variety of authorities in various countries to try to regulate how compost composition is determined. As practical users of compost, we have found the criteria listed in Table 1 to be useful in judging the quality of compost for premium vineyard development.

The composition of compost determines the suitability of the material for a particular task and possibly the maximum amount that can be applied. About half of most forms of commercial compost consist of carbon and much of the remaining half is oxygen and hydrogen. There are also lesser amounts of nitrogen, phosphorus and a large variety of other constituents. The composition of these lesser constituents depends on the source materials used for the manufacturing the compost. These source materials may introduce unusually high concentrations of chemical constituents such as soluble salts, plant nutrients (eg. nitrogen), heavy metals or physical contaminants such as plastic waste, wood chips, sawdust, metal, rock, etc. In some cases constituents are added to target particular soil amelioration requirements such as lime for acid soils and gypsum for sodic or magnesic soils.

Indiscriminate use of compost may give rise to problems caused by salinity, heavy metal accumulation, nitrogen fixation, diminishment of oxygen in the rhizosphere, raised soil temperature, accumulation of phytotoxic substances like organic acids of low molecular weight and pathogenic organisms.

The properties of immediate importance in judging compost quality for improving soil structural quality are compost maturity (ratio of carbon to nitrogen), salinity, sodicity, soluble nitrogen concentration (nitrate and ammonia), boron and heavy metal concentrations. These are explained below.

Table 1. Proposed compost standards for restoring optimum soil structure after vineyard establishment. From: Proceedings of the Soil Environment and Vine Mineral Nutrition Symposium. P. Christensen and D. Smart (Eds.). ASEV, Davis, CA. Copyright 2005. Reprinted by permission.

Element concentration	Symbol	Units	Critical value
General constituents and conditions:			
Plastic or rock > 0.5 inch	-	% dry mass	< 5
Electrical conductivity	EC_{se}	dS/m	see examples below
Reaction	pH	-	5 to 7.5
Extractable Calcium	Ca_{ex}	% dry mass	None
Extractable Magnesium	Mg_{ex}		$< Ca_{ex}/2$
Extractable Sodium	Na_{ex}		< 1
Soluble Ammonia Nitrogen	NH_{4SE}	mg/L of saturation extract (SE)	< 300
Soluble Nitrate Nitrogen	NO_{3SE}		< 42
Soluble Chloride	Cl_{SE}		Undecided
Soluble Boron	B_{SE}		< 100
Carbon:Nitrogen ratio	C:N	-	< 20
Moisture	-	% dry mass	> 25
Organic matter	OM		> 25
Extractable heavy metals (EPA 503 Standard):			
Arsenic	As	mg/kg dry mass	< 41
Cadmium	Cd		< 39
Cobalt	Co		< 34
Chromium	Cr		< 1200
Copper	Cu		< 1500
Lead	Pb		< 300
Mercury	Hg		< 17
Nickel	Ni		< 420
Selenium	Se		< 35
Zinc	Zn		< 2800
Derived parameters:			
Maximum application rate	-	ton/ha	See examples below
Sodium Adsorption Ratio	SAR_{SE}	-	< 6

Examples: Maximum ton/acre of compost to apply if mixed with soil - based on EC measurement of salt : max (tonne/ha) = 94.6 $EC^{-0.7}$

EC_{se} (dS/m) of compost:	1	5	10	20	30
Maximum rate (tonne/ha):	95	31	19	12	9

Compost maturity
Determines the physical, chemical and biological stability of the compost conferred by the degree of humification; measured by carbon-to-nitrogen ratio, ammonium level and salt concentrations (see Table 1).

Salinity
May produce toxic effects on vines; measured by electrical conductivity of compost saturation extract; determines the safe maximum amount of compost to apply; measured as electrical conductivity of a saturated past extract and interpreted using a sliding scale (equation 1) for salinity assessment as discussed below and shown in Table 1.

Sodicity
Degrades soil physical quality causing crusting, hard-setting, reduced infiltration rate, lower hydraulic conductivity; measured as the extractable sodium expressed as a proportion of the total mass of dry compost.

Soluble ammonia
High concentrations (>300mg/L) of soluble ammonia in compost indicate immaturity and have toxic effects on vines and damage vine roots; measured as the concentration of ammonia in a saturation extract of the compost.

Soluble nitrate
Excessive nitrate nitrogen concentrations (42mg/L) promote excessive vegetative growth of vines; measured as the concentration of ammonia in a saturation extract of the compost.

Boron
High concentrations (100mg/L) of soluble boron have toxic effects on vines; measured as the concentration of boron in a saturation extract of the compost.

Heavy metals
Accumulate in soil and may reach toxic levels, causing contamination of fruit, threatening the survival of vines and contaminating the environment; measured as extractable concentrations of various metal constituents and interpreted using the USA EPA 503 standard for environmental contamination (Table 1).

To judge the acceptable level of salinity to import into soil by applying compost, we use a sliding scale that restricts the amount of compost recommended, depending on electrical conductivity (EC) of a saturation extract from the compost. Assuming that the compost is to be thoroughly mixed with surface soil, we base this decision on the EC of a saturation paste extract of the compost, using the following formula as recommended by Standards Australia (1997):

$$M = 94.6\ EC^{-0.7} \qquad (1)$$

where M is the maximum amount (metric tonne/ha) of compost to apply at any one time to avoid salinity damage to young vines and EC is the electrical conductivity (dS/m) of a saturation extract of the compost.

Table 1 shows the maximum rates of compost application, calculated from this relationship, for hypothetical saturation extract electrical conductivity values of 1, 5, 10, 20 and 30dS/m. Most commercial composts sold have electrical conductivity values of less than 20dS/m and compost application rates of 12 tonne/ha are acceptable for newly developed vineyards. Animal waste products used to manufacture compost are often the main source of salt, so incorporation of excessive proportions of animal waste products into compost during manufacture should be discouraged.

Other contaminants such as weed seeds, herbicide, pesticide residues and pathogen populations may also need to be monitored. At this time we do not have practical, cost effective, reliable standards to judge the effect of these constituents on newly planted vines. However, documentation of the source of the constituents used to manufacture the compost can aid the user in assessing the probability that undesirable secondary constituents may be present. If this is likely, the user can take additional steps to assess the hazards of the contaminants.

Summary

Development and management of land for production of wine grapes is highly mechanised and vineyard soils are susceptible to physical deterioration resulting from aggregate pulverisation, compaction and reduction of soil organic matter. This introduces physical limitations to vine root growth which often translates into threats to vine survival and growth and ultimately fruit quality.

Compost has a beneficial effect on physically degraded soil, provided it is applied in conjunction with careful tillage and at rates high enough to be effective (10 tonne/ha or more). Application of compost for restoration of favourable soil structure following vineyard development has been shown to be particularly beneficial for early vine growth provided the compost is free of undesirable constituents.

The most opportune time to apply compost is at the development stage of the vineyard, before deep ripping, where it can be effectively mixed with soil by thorough disking after deep ripping. The most pressing factors dictating compost quality are:

- maturity
- salinity
- sodicity
- nitrogen
- heavy metal concentrations.

Critical values for these factors applicable to improving vineyard soil physical properties are proposed, allowing users to safely maximise compost application rates without degrading land quality by importing toxic contaminants in the compost.

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