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Compost production and use in horticulture

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Compost production and use in horticulture



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Bob Paulin and Peter O'Malley

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Department of Agriculture and Food
Government of Western Australia



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The contents of this report were based on the best available information at the time of publication. Conditions may change over time and conclusions should be interpreted in the light of the latest information available.

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Cover photographs:

The cover shows an example of good compost and a modern compost turning machine used by Custom Composts at Mandurah and other large scale modern compost producers.

Summary

Maintaining and improving soil organic carbon levels is becoming an increasingly important aspect of modern farming. Compost provides potentially one of the most effective ways of applying organic matter to soils and improving organic carbon levels.

Improving soil organic carbon is directly related to soil quality and performance. Increased quality reflects improved biological function (soil health), fertility and physical attributes that include better drainage, reduced compaction and erosion, and improved moisture-holding capability, at least for lighter soils.

Compost is not the only option available. Others include the use of cover or break crops, reducing the use of cultivations, selecting safe pesticides that have little or no impact on beneficial soil biology and the adoption of practices such as permanent bed systems.

Using compost particularly, in intensive industries such as vegetable production, has demonstrated potential to reduce the need for fertiliser, irrigation and pesticides, and to improve marketable yields. It is also likely to improve produce quality and extend shelf life.

Compost use has a number of other benefits that result from the composting process. They include stabilisation of nutrients that minimises leaching of nitrogen in particular, pasteurisation that avoids risks of spreading pests, diseases and weeds that are associated with raw organic matter. By blending different feedstocks, composting can reduce contaminant levels including heavy metals, and the process also degrades most organic compounds that are of concern.

In addition to potentially improving grower returns, the use of composted organic materials from both urban and agricultural sources will make real contributions to reducing carbon emissions and protecting groundwater quality.

The degree to which compost use improves returns will depend on capturing the financial benefits that accrue as soil organic matter increases. It will also be important to ensure that the improved environmental outcomes for the wider community are passed on to the composting industry and users of compost.

Most other forms of organic matter such as manures, while usually cheaper, have significant disadvantages when compared with compost including:

- nutrients that are readily leached to groundwater
- presence of diseases and/or weeds and pests
- smaller contributions to soil carbon and therefore to improving soil performance
- fewer fly breeding issues including the troublesome stable fly
- unpleasant odours.

Nationally and internationally, there is growing pressure to cease using raw manures because of environmental and health concerns. Using composted manures manages these concerns.

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What is compost?

Compost is stable aerobically decomposed organic matter. It is a biologically active material mostly of organic origin that can vary in texture. It is typically dark brown with an earthy appearance and smell. A good example is shown in Figure 1.

Compost is the result of a managed decomposition process in which successions of aerobic micro-organisms break down and transform organic material into a range of increasingly complex organic substances, many of which are loosely referred to as humus.



Figure 1. Example of good compost

These substances are responsible for many of the important characteristics of high quality, healthy soils including their ability to hold plant-available nutrients and moisture.

Compost is ideally made from a mixture of organic materials that are blended to achieve an appropriate carbon to nitrogen ratio. Regardless of the method used, the composting process is managed to maintain temperature, oxygen and moisture levels within accepted ranges.

Compost can be produced using a range of equipment from basic pile turning with front-end loaders to sophisticated in-vessel processing. However it is process management rather than equipment that determines compost quality.

Types

For horticulture, the major consideration is whether the compost is best suited to soil incorporation prior to crop establishment, or as surface-applied mulch after the crop has been established.

Soil incorporation

Good quality compost is most readily achieved with non-woody organic materials such as crop waste, straw and leafy materials. This is because the carbon in these materials is readily degraded and they develop a crumb structure that is like soil in appearance. Addition of clay materials can further enhance this characteristic.

Similar quality compost can also be made from lignified woody materials. However, because the carbon from these sources is more difficult to degrade, it can require longer processing to achieve a given level of maturity. Composting time for woody materials is reduced by increasing the level of milling or grinding because it exposes more of the carbon to microbial action. The use of purpose-built turning equipment rather than front-end loaders will also speed up the composting process. This is because of their superior ability to thoroughly mix and aerate materials within the compost pile.

Composts based on woody green organic materials can, depending on age and coarseness, contain undecomposed woody material. Soil incorporation processes, particularly involving rotary cultivators, will further break up this woody material, exposing the undecomposed material to microbial attack. The resultant increase in microbial activity increases the demand for nitrogen that can potentially compete with the crop for available nitrogen and reduce crop growth.

For this reason, woody green waste-based composts should be screened with a 10 mm or finer screen to minimise the risk of undecomposed materials being present.

Mulches

Compost marketed as mulch is normally made from a higher proportion of green waste and woody materials and will therefore have a lower nutrient content.

It may be screened to remove large particles and sometimes the finer material because the primary purpose is to provide a protective blanket over the soil that reduces moisture losses, moderates soil temperatures and reduces weed growth.

These composts are widely used in orchards and vineyards where improvements to yields without measurable reductions in fruit or grape (from a winery perspective) quality have been reported. Figure 2 illustrates how composted mulch applied at 50 mm depth in a 0.5 m wide strip maintained soil moisture levels in a vineyard at Frankland in the Great Southern region of Western Australia.

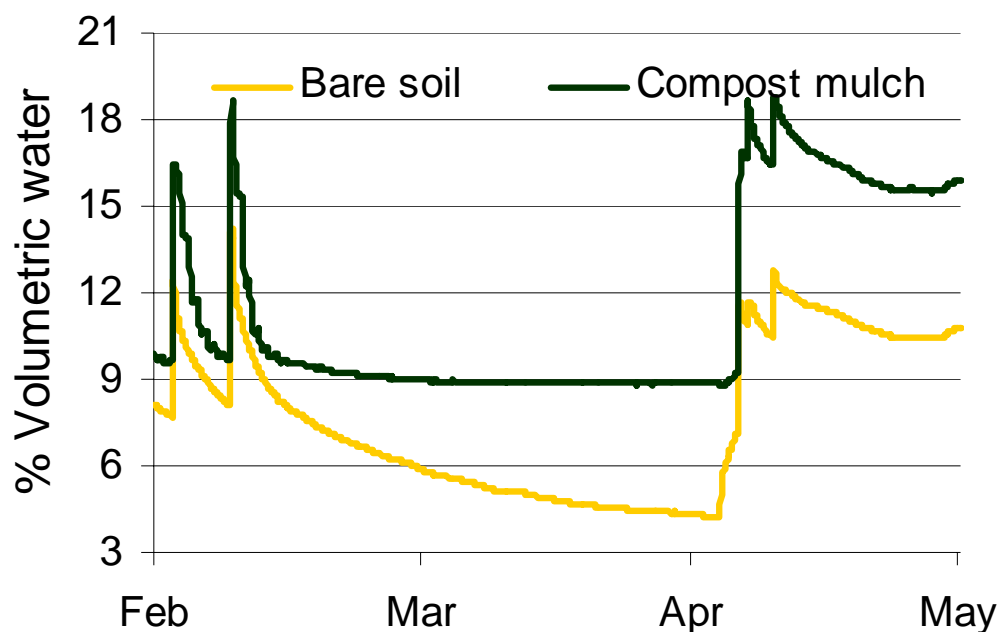


Figure 2. Soil moisture measured at 60-90 cm depth in a vineyard at Frankland

Pasteurised and raw mulches

To be classed as pasteurised mulch, the composting process needs to meet pasteurisation requirements defined in the Australian Standard™ AS 4454–2003 for Composts, soil conditioners and mulches, such as achieving pile temperatures above 55°C for a minimum three days, following three consecutive turns.

Active decomposition associated with these materials means that the microbes, mainly bacteria, have a large demand for nitrogen. Consequently these materials have the potential to compete with crops for nitrogen, and consideration should be given to providing additional nitrogen to counter this possible effect.

To minimise growth reduction when using pasteurised mulch, minimum quality standards including a C:N ratio less than 35:1 and a Nitrogen Drawdown index (NDI) above 0.3 are suggested. The NDI measures the potential for a product to compete with a crop for nitrogen.

Mulches that have not satisfied pasteurisation requirements as defined by AS 4454 are likely to introduce disease, pests and weeds. This is unacceptable unless they are spread within the property from which they were derived.

Spreading raw mulches has resulted in the rapid and wide distribution of a number of disease and weed problems in particular. This is totally unacceptable to agriculture, leading to increased pesticide usage and other costs associated with their management.

More important is the increased biosecurity risk posed by raw mulch. The inevitable delays in detecting the arrival of a new (exotic) pest, disease or weed, can mean it has been widely distributed by the time it is detected.

This was highlighted when raw mulch was identified as a major cause of the rapid spread of a phytophthora disease, sudden oak decline, in California. This potential risk has been recognised in the new Biosecurity and Agricultural Management (BAM) Legislation in Western Australia.

Benefits

The benefits of using compost largely result from its effects on both the quality and level of soil organic matter and in its potential to increase stable soil carbon levels.

Soil organic matter

Soil organic matter is the third and arguably the most important aspect of soil (Figure 3) because of its potential to improve the other two (physical and chemical) components and collectively improve soil quality resulting in:

- better crop performance and crop quality
- improved nutrient and irrigation efficiency
- increased infiltration and reduced compaction
- reduced nutrient leaching and increased nutrient-holding capacity
- reduced need for pesticides.

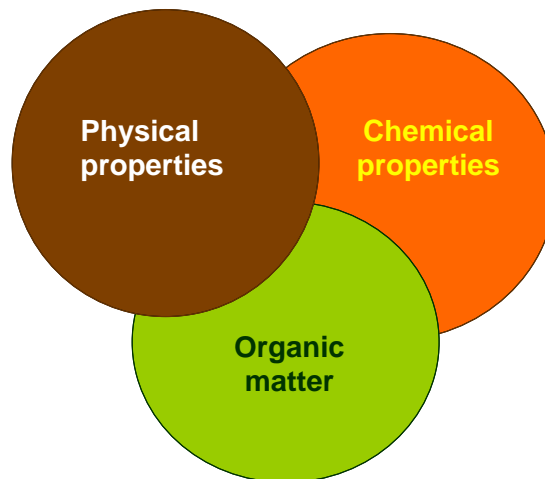


Figure 3. Three aspects of soil quality

These improvements relate to better soil quality from improved biological activity (soil health), fertility and physical characteristics that include better moisture-holding and drainage, and reduced soil compaction and erosion.

Increasing soil organic carbon improves most if not all aspects of crop production including the capacity to address potential environmental concerns. The amount of improvement will be determined by how much we can increase soil organic matter levels.

Soil organic matter reflects the decomposition of organic materials by the actions of vast number of soil organisms that are collectively referred to as the soil food web. These are responsible for returning organic materials to the soil and for maintaining its quality and performance. Decomposition produces a large range of carbon-based compounds including simple sugars that fuel biological activity, cellulose cementing agents that contribute to soil structure and humic substances. The humic substances play a critical role in delivering most of the benefits associated with increased soil organic matter and ultimately are responsible for increasing stable soil carbon levels.

This dynamic process requires regular additions of organic material. Composting not only deals with the risks associated with raw organic materials but importantly produces material that can contain significant levels of humic substances that directly increase stable organic soil carbon.

Increasing soil organic matter improves soil structure, water infiltration, soil aeration, combats compaction and increases the soil's water-holding capacity. In sandy soils, organic matter increases nutrient-holding capacity and is associated with increased organic nitrogen levels that can be mineralised to provide crop nitrogen. Adequate soil organic matter also counters acidification caused by most fertilisers. The associated increases in biological activity and diversity can reduce diseases and pests.

One important aspect of these active decomposition processes is mineralisation, the process that releases nutrients, in particular nitrogen, for use by plants. This process enables organic systems to achieve good crop production while restricting groundwater nitrate to environmentally safe levels, something that is almost impossible to achieve when there is low soil carbon and exclusive reliance on fertiliser nitrogen use. Using compost will improve the capacity to produce safe 'clean green' horticultural produce and importantly increase the potential for large-scale organic food production.

By reducing potential damage to soil and water resources and increasing the ability to manage nitrate-nitrogen losses to groundwater, compost use should improve the security of existing soil and water resources and improve future access to additional sources.

In summary, using compost can be expected to:

- Improve crop performance and lower production costs through:
 - improved yields, product quality and storage life
 - more efficient and reduced use of fertilisers and pesticides, including soil fumigants
 - better utilisation of irrigation
 - increased crop resistance to pests and diseases.
- Improve soil quality through:
 - better organic matter levels and organic cycles
 - increased available water to plants
 - increased nutrient availability and nutrient-holding capacity
 - improved structure
 - reduced soil-borne plant pathogens and pests.

Contribution to crop nutrition

Soil fertility is associated with mineralisation of nutrients contained in organic matter and their release in plant-available form to the soil solution. Mineralisation is the result of normal biological cycles within the soil and can be stimulated by the addition of appropriate quality compost and cultivation. Because mineralisation occurs over extended periods it can make important contributions to plant growth and to minimising the impact of leaching associated with rainfall and excess irrigation.

In biologically active soils any available nutrients will stimulate additional microbial growth which further aids nutrient retention. The net result is that crops require less fertiliser and fewer nutrients are leached to the groundwater.

Compost is derived largely from plant materials (typically 80 per cent of the initial mix), so its nutrient content will be similar to that of most crops. The nature and ratios of the materials or feedstocks used in its manufacture will influence the nutrient content of the compost produced. Depending on the rate used, compost therefore has the potential to supply a significant proportion of a crop's total nutrient needs.

The following suggested nutrient contributions from compost to horticultural crop production are based on research findings and interpretation of overseas information. They are intended only as a guide because they have had limited commercial validation.

Nitrogen contribution

Nitrogen in compost is mainly in an organic form unavailable to most plants. This explains why most research into crop availability suggests that following compost application only 20 to 30 per cent of its total nitrogen will be available to crops. With repeated applications, it is possible to build significant reserves of organic nitrogen, even in coarse sandy soils, and mineralisation of this organic nitrogen pool can release available nitrate-nitrogen to plants over extended periods. The level of mineralisation will vary with climate, soil type, compost type, and the size of the organic nitrogen reserve.

Nitrogen levels in compost rarely exceed 2 per cent and are typically in the range of 1.0 to 1.5 per cent on a dry weight basis. Based on 20 to 30 per cent of compost nitrogen becoming available to a crop following application, 20 cubic metres of compost is likely to contribute 20 to 35 kg of nitrogen, equivalent to 43 to 76 kg of urea. This assumes that the compost has appropriate maturity, contains 1.25 per cent dry weight (% DW) nitrogen, 40 per cent moisture content and a density of 0.75 tonnes per cubic metre (t/m^3).

Recent work with compost in vegetable crops initially demonstrated large increases in soil organic nitrogen, but indicated that only 10 per cent of the nitrogen was being used by the crop. Low soil nitrogen levels and poor compost quality may explain this initial low utilisation, as later work showed compost of the correct quality stimulated the release (mineralisation) of available nitrate-nitrogen to plants from both soil reserves and the applied compost.

Nitrogen-related quality criteria are listed in Table 1 and include a carbon to nitrogen ratio (C:N) of less than 20, total nitrogen above 1.0 per cent dry weight, soluble nitrogen above 100 mg/kg, with at least some nitrate-nitrogen present (nitrate:ammonium ratio above 0.14).

As soil reserves of organic nitrogen increase, significantly greater mineralisation can occur. After long-term use of compost, we have recorded mineralised nitrogen equivalent to 150 kg/ha of applied fertiliser being made available to a crop grown in coarse sand.

The great advantage of the mineralisation process is that highly soluble, and therefore leachable nitrogen, is continuously replaced. This can result in significant yield improvements and less need to re-apply fertiliser to crops after rainfall during wet seasons.

Another advantage of this increased mineralisation process is to reduce nitrogen leaching. Trials have demonstrated that soil enriched with compost can produce equivalent or better marketable yield with less than half the normal mineral fertiliser use.

Phosphorus, potassium and magnesium contributions

Phosphorus

Current soil testing procedures can be used to estimate phosphorus fertiliser requirements. Results on coarse sandy soils indicate that 40 per cent of the phosphorus applied through compost is in similar forms as occur in superphosphate.

Phosphorus content will depend largely on the feedstock used and range from 0.3 to 0.9 per cent dry weight. Manures have a relatively high phosphorus content compared to plant-derived organic materials. Manure-based composts will be at the high end of this range while compost based on woody green material will be at the lower end.

Therefore with phosphorus content between 0.3 and 0.9% DW, 20 m^3 of mature compost will contain 27 to 81 kg of phosphorus. Forty per cent or 11 to 33 kg of this will initially be available and would therefore replace or be equivalent to 121 to 363 kg of superphosphate. This assumes 40 per cent moisture content and a density of 0.75 t/m^3 .

Potassium

The potassium contained in compost is totally available and in soils with very low cation exchange, such as coarse sands, compost will increase cation exchange and reduce potassium fertiliser requirements by up to 20 per cent after two to three applications.

Compost normally contains between 0.8 and 1.0 per cent of potassium on a dry weight basis. Research indicates that it is used 20 per cent more efficiently than potassium supplied by fertiliser.

Therefore with a potassium content of 0.8 to 1.0 per cent (dry weight), 20 m³ of mature compost would contain 72 to 90 kg of potassium that would be totally available and after three applications would reduce fertiliser potassium requirement by 20 per cent. This would provide between 80 and 100 kg/ha of potassium and be equivalent to 193 to 240 kg of potassium sulphate initially, and 132 to 283 kg after three compost applications. Again, this assumes that the compost has 40 per cent moisture content and a density of 0.75 t/m³.

Magnesium

Our work indicates that magnesium is totally available in compost and results in similar effects to those achieved with potassium.

Therefore with a magnesium content of 200 to 250 mg/kg, 20 m³ of mature compost would contain 16 to 20 kg of magnesium. Initially this would be equivalent to 160 to 204 kg of magnesium sulphate and as with potassium, would increase by 20 per cent to between 192 and 245 kg after three compost applications. Again, this assumes that the compost contains 40 per cent moisture and has a density of 0.75 t/m³.

Production

Compost is made from a wide range of organic materials including all plant and animal products and crop, food, manure, timber and paper wastes. Inorganic materials such as clay, fly ash (from power generation) and potentially other by-products of the mining and mineral sands industries such as bauxite residue or 'Alkaloam' can also be included. These non-organic materials can be used to modify compost quality and characteristics.

Best quality compost is made from wastes that are separated at source (Figure 4) or a known blend of materials such as green waste containing food. Source-separated feedstocks provide blending options that maximise composting process efficiency by allowing:

- adjustment of the carbon to nitrogen (C:N) ratio and rate of biological activity
- adjustment of porosity that assists with managing aeration
- reduced contaminant levels.



Figure 4. Urban kerbside green waste - excellent clean feedstock for compost

Composting equipment ranges from various physical turning and aeration devices to forced aeration static pile and in-vessel systems (see Figures 5 to 7).

Depending on the location and nature of the materials, composting may be carried out outdoors, indoors or within enclosed vessels. Enclosed systems are expensive to establish, but can provide maximum control over the composting process and odours.

Regardless of method and equipment, composting is an aerobic process that requires good process management to ensure and maintain:

- C:N ratio in the range of 25 to 35:1
- adequate oxygen levels
- moisture levels between 40 and 60 per cent
- temperatures below 70°C and preferably between 55 and 65°C.

The C:N ratio is adjusted by blending the different feedstocks. Values for a number of materials along with typical density and porosity ratings are provided in the Appendix.



Figure 5. In-vessel composting (Southern Metropolitan Regional composting facility, Canning Vale)



Figure 6. Modern large-scale compost turner in use at Mandurah

In addition to careful management of feedstock, producing consistent compost quality requires regular monitoring (Figure 8) of temperature, moisture and oxygen levels. If too hot, this will destroy the composting micro-organisms; if too cold, this temperature will be insufficient to destroy diseases, pests and weed seeds. Adequate moisture is also important as the activity of microbes will decline when moisture levels drop below 40 per cent. The hand squeeze test can be used to estimate moisture levels. Adequate moisture is indicated when some moisture appears after squeezing a handful. It is too dry if the material falls apart when the palm is opened. As moisture content increases above 60 per cent, the risk of low oxygen or anaerobic conditions increases rapidly, resulting in longer composting time and potential for reduced quality.

The use of coarse-textured feedstocks to improve porosity will make it easier to maintain adequate oxygen levels.



Figure 7. Static pile composting involves aeration with forced air (Biowise Composting Facility, Medina)



Figure 8. Regular monitoring is essential for consistent compost quality

Composting involves two critical phases that are characterised by the temperatures achieved within the composting pile or windrow. Figure 9 represents an ideal in-vessel or static pile system where continuous management of conditions makes it possible to maintain steady temperature. In windrow composting, regular turning results in temperature decline followed by recovery as the composting process re-establishes itself.

Composting phases

| | |
|------------------|--|
| 1st phase | <p><i>High temperature (thermophillic) phase.</i> Temperature exceeds 55°C but needs to be maintained below 70°C by turning and forced aeration.</p> <p>Conventional outdoor composting usually requires six to eight weeks and regardless of the composting method, should be greater than three weeks (see Figure 10) considered to be the minimum requirement for in-vessel processes.</p> <p>This phase culminates in the production of stable compost that can be stored safely. It is the period of greatest volume reduction.</p> <p>Effective pasteurisation and control of diseases, pests and weeds will occur if temperatures above 50-55°C are maintained for four to five days. The beneficial microbes that are responsible for the composting process can survive temperatures up to 70°C.</p> <p>Well managed aerobic composting generates temperatures that kill the disease, pest and weed contaminants that can be present in organic materials. A quirk of nature is that the organisms that decompose organic materials can survive these temperatures. In windrow composting, the conditions need to be achieved over a minimum of three turns to ensure that all the material is effectively pasteurised and therefore safe to use. These conditions are defined in the Australian Standard for Compost, soil conditioners and related products (AS 4454).</p> <p>With completion of the thermophillic phase, the composting material stabilises, meaning that it can now be considered to be compost. At this point, the composting temperatures and more importantly, the production of carbon dioxide or the consumption of oxygen, have begun to decline.</p> |
| 2nd phase | <p><i>The cooling or maturation (mesophyllic) phase.</i> As maturation progresses, the core temperature of the composting pile continues to decline and will eventually reach ambient temperatures.</p> <p>By definition, compost must have achieved stability, however it will still be too immature for use in many situations and generally should be matured further. Composts that are relatively immature provide greatest nutritional benefits but highly matured compost has higher humus levels and delivers better outcomes in terms of soil quality.</p> <p>Continued management is important throughout the maturation phase. Techniques for measuring compost maturity and therefore its potential value are not well developed.</p> |

Nitrogen is required to increase microbial activity that degrades or breaks down the carbon-rich organic materials such as straw, crop waste and green waste. Nitrogen is usually derived from manure, however a number of fresh, green/leafy organic wastes and food wastes have adequate carbon to nitrogen ratios for them to compost without the addition of extra nitrogen.

Feedstock selection and blending ratios are used to achieve optimum C:N ratios of between 25 and 35. High nitrogen levels (or low C:N ratio) accelerate microbial activity and maintaining temperatures below 70°C becomes difficult. This situation also results in nitrogen losses. If nitrogen levels are too low, the composting process will be slow and may fail to achieve adequate pasteurisation.

When determining the C:N ratio of the materials to be composted, consideration needs to be given to carbon availability. With woody materials, the total amount of carbon determined by analysis is much greater than the amount immediately available to the composting process. The available carbon is the proportion that is exposed to microbial attack.

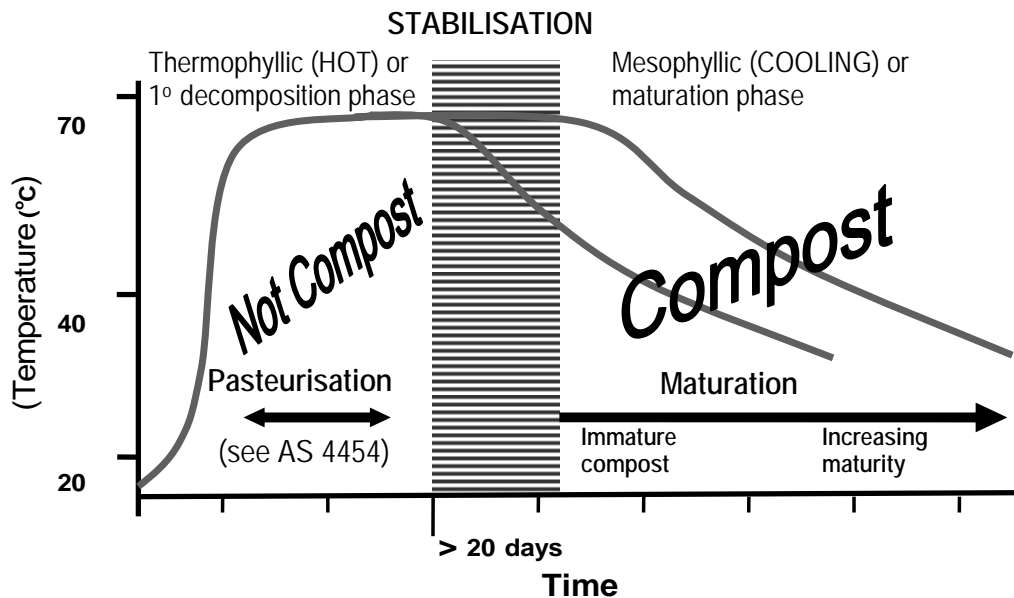


Figure 9. Temperature changes during in-vessel and static pile composting process

Storage

Composting is a continuous process, therefore maintaining a given maturity or quality requires biological activity and storage time to be minimised.

The biological activity depends on moisture levels, so allowing compost to dry out will permit storage with minimal change to the quality.

When storage is required, continue turning the compost without any addition of water until moisture levels approach 30 per cent, then push it into large heaps and leave without further turning. Ideally it should be rewet prior to marketing in order to minimise dust during spreading.

Quality

Compost quality is complex and is related to the intended use of the final product. Aspects include its maturity, type, nutrient content and levels of contaminants. Useful measures include the C:N ratio, total nitrogen, available nitrogen including the nitrate to ammonium ratio, and Nitrogen Drawdown Index (NDI).

Potential contaminants include disease, pests and weeds, inert materials such as plastics in all its forms, metal, glass and heavy metals.

Many heavy metals are important crop nutrients and compost often contains substantial levels of zinc and copper, in particular. This is beneficial to many Western Australian soils that are typically deficient in the elements. However if compost with copper and zinc levels approaching 100 and 200 ppm respectively are applied regularly, it would be advisable to test soil levels periodically to ensure that they do not become potentially toxic to crops.

Compost processes minimise these risks and quality assurance systems ensure that the risks are managed within acceptable limits. Most professional compost producers will have a quality assurance system and preference should be given to those that are independently audited.

Stability and maturity

Stability defines the completion of the initial thermophilic phase of composting (see Figure 9) and is a prerequisite for a product to be called compost.

Maturity reflects the level to which the second (mesophilic) phase of composting has proceeded. Maturity is the single most important determinant of compost quality because of its influence on crop yields and quality. Humic substances develop during maturation and the time required to reach a particular phase of maturity depends on the feedstocks and the process used, woody materials generally take longer.

Measuring maturity is not simple and a consistent conclusion from extensive research is that it cannot be defined by a single measurement. The compost maturity index evaluated in vegetable production (Buchanan 2002) for the Californian Compost Quality Council (CCQC) has considerable promise. The index is derived from the C:N ratio together with a measure of toxicity, such as seedling root growth and a measure of stability, such as carbon dioxide production.

The index gives compost a maturity rating between 1 (immature) and 5 (highly mature). Validation field studies indicated that for vegetables, index values around 2 gave the best results, particularly in terms of contributions to soil fertility.

Prior to commencing local research, we used earlier work and the literature to define a set of quality requirements for compost to be used in vegetable production (see Table 1). Comparing results over 18 trials against compost performance suggested that C:N ratio and various measures of nitrogen were most consistent indicators of the best compost for vegetable production.

An asterisk in Table 1 indicates these ideal values and it is likely that collectively they result in greater mineralisation of plant nutrients and in particular, increased crop-available nitrogen. The type of plant-available nitrogen present is also important and some nitrate-nitrogen needs to be present as indicated by a nitrate to ammonium ratio greater than 0.14. The potential for compost to compete for nitrogen, measured by the NDI, can also be a useful indicator of compost quality but is a relatively expensive analysis to perform.

Table 1. Critical analysis values, conducted to Australian Standard AS 4454 and based on DAFWA's compost research and development program

| Measurement | Value | Unit | Comment |
|--|---------|------|---|
| * Carbon to nitrogen (C:N) ratio | <20.0* | - | For crop-available nitrogen |
| Nitrogen Drawdown Index (NDI) | >0.5 | - | Lower values likely to compete for crop N |
| * Total nitrogen | >1.0* | % DM | |
| * Ammonium + nitrate-nitrogen | >10.0* | mg/L | Also indicates nitrogen availability for crop |
| * Nitrate:ammonium ratio | >0.14* | - | High ammonium level indicates immaturity |
| Organic matter | >35.0 | % DM | The higher the better |
| pH _{Ca} (measured in calcium chloride solution rather than water) | 5.0-7.5 | | Ideally around neutral or pH 7.0 |
| Electrical conductivity | <60.0 | mS/m | Equals 6 dS/m |
| Toxicity (potting mix test) | >60.0 | % | Low levels indicate insufficient composting |

* critical values indicating that compost is likely to be suitable for vegetable production

Application

Application rates, timing in relation to crop establishment, and placement, are all factors that can influence results. Traditionally compost is broadcast and incorporated close to planting, however when compost is immature and likely to create problems with establishment, such as with small-seeded crops such as carrots, then allowing 10 to 14 days delay will minimise potential problems.

Strategies for efficient use

Maximum benefits from compost require regular, repeated use.

As soil organic matter levels and microbial populations develop, significant reductions in fertiliser, irrigation and pesticide applications will be possible. Soil organic carbon levels are influenced by:

- soil type - they are lower in light sandier than heavier soils
- management - cultivation in particular reduces levels
- climate - lower in dry arid and warm humid climates.

Improved performance achieved with sandy soils on the Swan Coastal Plain, have been associated with increasing organic carbon levels to around 1 per cent on a dry weight basis. However it is generally accepted that to fully achieve potential benefits and in particular to maximise irrigation savings, levels need to approach 2 per cent in our sandy soils.

Suggested rates for using compost and mulch compost in various horticultural crops are provided in Table 2. For vegetable production on light sandy soils, trials and commercial experience suggest that rates in the order of 20 to 25 m³/ha are sufficient to achieve significant results. Reduced volumes by either banding (Figure 10) or restricting placement to the planting beds (Figure 11) are likely to maintain or even improve crop establishment but are unlikely to achieve the same increase in soil carbon.



Figure 10. Specialised placement of compost (courtesy Custom Composts)

In the longer term, it is feasible that lower rates of 10-15 m³/ha/year will be sufficient. However, it must be stressed that rates will be determined by the adoption of management practices that promote soil organic carbon levels and the maintenance of effective soil organic cycles. These include reduced cultivation, greater use of cover or break crops, as well as minimising the use of pesticides, fertilisers and other practices that disrupt beneficial microbial populations.

The addition of clay, either directly or as a component of compost, will also assist organic matter build-up. This is because of its positive influence in creating a wider range of pore sizes that in turn provide a more protective environment for the important microbial component of the soil biology, the 'soil food web'.



Figure 11. Compost applied only to planting bed (courtesy Custom Composts)

Table 2 provides a preliminary guide to selecting compost for either soil incorporation (vegetable production and orchard/vineyard establishment) or application as surface mulch.

Note that the values provided in Table 2 are recommendations based on our collective knowledge and the results of trials over extended periods in which crop levels and compost analysis have been compared.

Table 2. Suggested rates and critical quality factors for using compost in horticulture

| Factor | Soil incorporation | | Surface mulch |
|---|------------------------------------|---|---|
| | <i>Vegetables and annual crops</i> | <i>Orchard, vineyard and perennial crop establishment</i> | <i>Orchards, vineyards and perennial crops</i> |
| C:N ratio | <17 | <20 | Not as critical, prefer <35 to minimise N competition |
| NDI (Nitrogen Drawdown Index) | >0.6 | >0.5 | Not critical, prefer >0.3 to minimise N competition |
| Electrical conductivity (mS/m) | <60.0 | <80.0 | <80.0 |
| pH | 6.5–7.5 | 6.0–8.0 | 6.0–8.0 |
| Moisture content (% dry matter) | >35 | >35 | >35 |
| Total nitrogen (mg/kg) | >1.5 | >1.0 | Not critical, prefer >0.7 |
| Soluble nitrogen (mg/kg) | >100 | >100 | Not critical |
| Nitrate:ammonium ratio | >0.14 | >0.14 | Not critical |
| Toxicity % | >60 | >60 | >30 |
| Application rate, suggested typical range | 15-30 m ³ /ha | 25-75 m ³ /ha trenched into planting rows | 50-75 mm depth to 15-25% of land centred on the row |

Markets

In any situation, the success of composting will be determined by the balance between production costs and the returns from the benefits provided. Costs include raw material assembly, processing, distribution and spreading. Returns need to reflect the benefits to the user together with recognition of the contribution that compost use makes to the environmental costs of managing organic wastes.

Compost user benefits need to reflect all of the benefits associated with improvements to soil performance including soil fertility and health (savings in fertiliser and potentially pesticide use), irrigation and benefits from reduced erosion from both rain and wind. The wider environmental benefits to organic waste management need to include contributions to managing soil and water quality and to reducing carbon emissions.

Agriculture is widely regarded as one of the major compost markets and its development was motivation for the National Compost Roadmaps program that was established in 2003. Around the world, agricultural use of compost varies enormously and success usually reflects the market development approaches adopted. Invariably quality and applied cost relative to measurable returns are the main determinants of progress and overall this market continues to be poorly developed. California is a notable exception, as is the viticultural industry in South Australia, particularly around Adelaide.

The reality is that the regular use of appropriate quality compost will increase returns. These improvements will increase over time. However it will be essential for farmers to make adjustments to management that translate the benefits into better returns.

Compost production has grown significantly in recent years and this growth is likely to accelerate in coming years. In Western Australia, production is largely based around Perth where a number of companies produce composts from a range of agricultural and metropolitan waste streams. Factors such as increasing landfill reduction targets, increased landfill levies and restrictions on the use of raw manure are likely to increase compost use.

Compost is used in a wide range of horticultural crops and some broadacre crops, as well as domestic and commercial landscape situations. Revegetation following mining and road construction, and remediation of contaminated sites are other markets with growth potential.

Horticulture, with its relatively intensive nature and potential for continued strong growth is a very important market. However, this growth is being constrained by concerns about compost quality, limited knowledge of both its benefits and how best to use it, and the cost that is typically incurred before crop establishment.

Many horticultural industries, especially vegetable production, have the added advantage of being close to population centres that generate large volumes of feedstock for compost manufacture. Ultimately, compost use by horticulture and agriculture will be dependent on accessing adequate quality feedstocks from urban centres.

The compost industry has been well served by the Australian Standard for compost and related products (AS 4454), however it does not address specific requirements of various market sectors. Recognising this, Compost Australia, the National Recycled Organics group within the Waste Management Association of Australia (WMAA), is developing quality standards and minimum information requirements to facilitate purchase of products that are appropriate to the intended use.

Use in vegetable production

Work with compost in vegetable production has demonstrated its potential to substantially improve soil quality and performance by increasing soil organic carbon levels. As shown in Figure 12, without the addition of compost, organic matter levels tend to decline. Its impacts on a range of soil quality measures are shown in Table 3.

Management, soil type and climate influence soil organic carbon levels and will determine how much compost is needed to maintain healthy, functional soils.

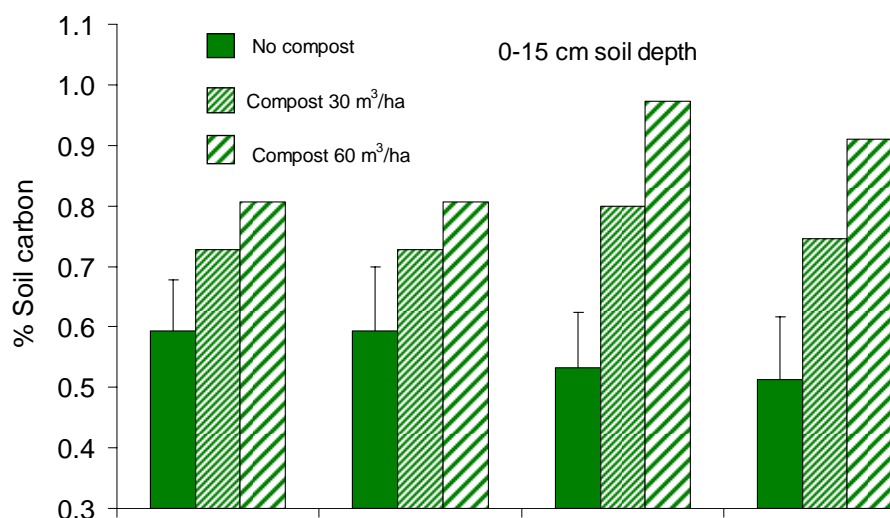


Figure 12. Changes in soil carbon levels over consecutive crops at the Medina Research Station

The use of compost in horticulture has the potential to make significant contributions to the continuing growth of these industries. In addition to improving yield and reducing fertiliser, irrigation and pesticide inputs, compost can minimise the adverse affects of continuous intensive cropping on soil performance and water quality.

Maximising the benefits of compost to horticultural productivity and sustainability requires repeated use, fertiliser adjustment to accommodate nutrients supplied and improved soil fertility and performance, and changes to production practices.

The range of improvements to soil performance indicated in Table 3 is generally influenced by the compost application rate and apart from increased soil moisture-holding includes:

- reduced bulk density, which results in increased soil aeration and potential crop root growth
- increased cation exchange capacity (CEC) or the ability to hold cations such as calcium, potassium and magnesium, which explains the 20 per cent reduction in potassium requirement associated with compost use
- stabilised pH in the neutral range that suits most crops
- retention of total nitrogen and therefore the potential release of plant-available nitrogen along with reduced leaching risks.

Compost use has produced the most consistent improvements with broccoli (Figure 13) and lettuce (Figure 14). With carrots, improvements have tended to be small and variable.

However in the most recent work with carrots, reducing normal nitrogen applications resulted in significantly improved marketable yields (Figure 15).

Table 3. Soil properties at Medina Vegetable Research Station after seven compost applications

| Treatment | Soil carbon (%) | Volumetric water (%) | Bulk density (t/m ³) | CEC (c mole/kg) | pH _{Ca} | Total N (%) |
|---------------------------------|-----------------|----------------------|----------------------------------|-----------------|------------------|-------------|
| Control | 0.51 | 10.12 | 1.429 | 2.71 | 5.85 | 0.027 |
| Compost @ 30 m ³ /ha | 0.75 | 11.99 | 1.365 | 6.17 | 6.80 | 0.048 |
| Compost @ 60 m ³ /ha | 0.91 | 14.17 | 1.321 | 8.53 | 6.85 | 0.065 |
| LSD* | 0.10 | 0.410 | 0.023 | 1.08 | 1.79 | 0.005 |

* Least significant difference – the minimum difference between values that can be considered statistically different at the 5% level of confidence.

This improvement to marketable carrot production is most likely to have been the result of improved soil quality and the associated increases in soil nitrogen reserves, however the benefits were achieved when we reduced nitrogen rates, emphasising the importance of maintaining correct plant nutrition.

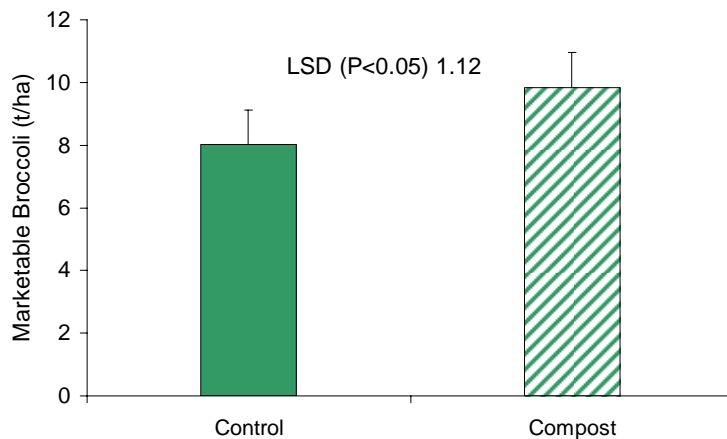


Figure 13. Increased broccoli yield with 30 m³/ha of compost

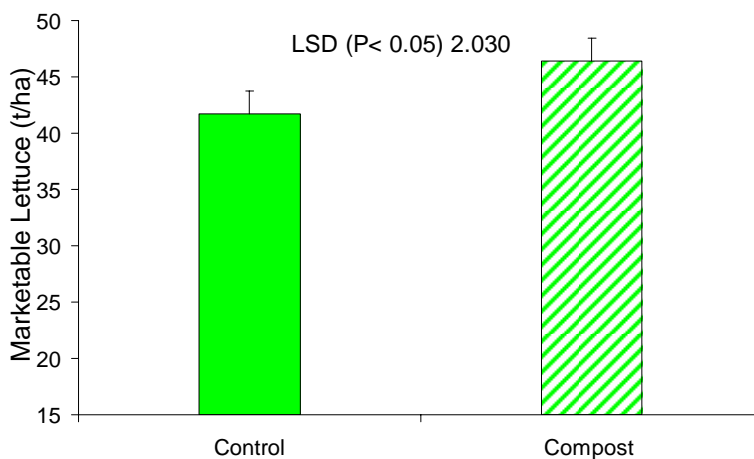


Figure 14. Increased lettuce yield with 30 m³/ha of compost

This result also supports the potential for improved soil quality associated with compost use to maintain production levels and reverse widely experienced trends for declining carrot yields over successive cropping cycles.

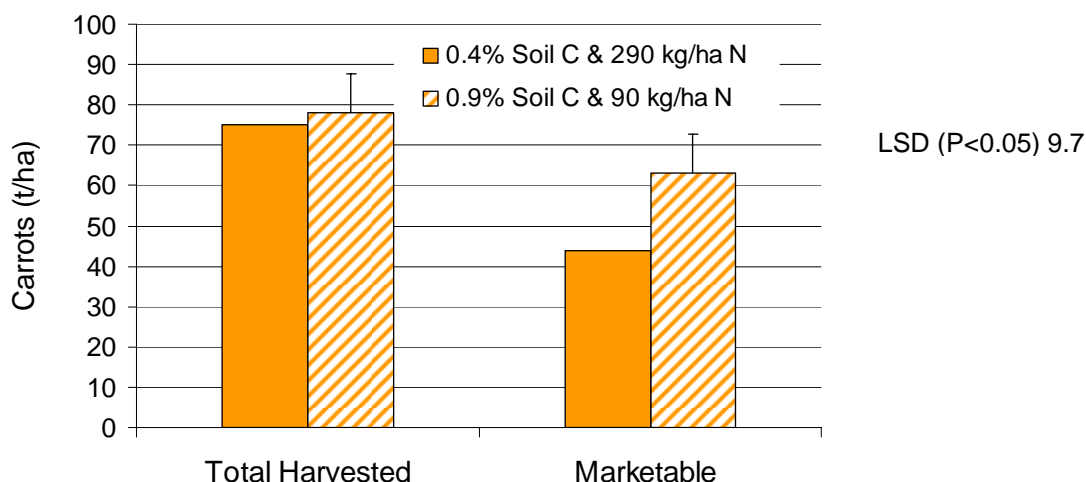


Figure 15. Impact of compost use with adjustment in nitrogen application on carrot yield

Use in fruit and vine crops

Most of the work in fruit and vine crops has involved the application of compost mulches or the use of compost in orchard and vineyard establishment.

Improved citrus, avocado and apple tree establishment has been achieved when good quality compost has been incorporated in the root zone at planting. Improved tree growth and yields have also been recorded for apples and both table and wine grapes, although levels of improvements were generally not as large or as consistent as recorded in South Australia (Buckerfield & Webster 2003).

In situations of limited water, mulches have demonstrated a capacity to better conserve and utilise available soil reserves. This effect combined with lower water availability is a likely explanation for the generally better results achieved in South Australia (Buckerfield & Webster 2003).

The use of compost and compost mulches in fruit and vine crops will be of most benefit when growing conditions are less than optimal and particularly when water availability is restricted. Their strategic application to areas where soils are not as good or to poorer performing areas can be used to improve uniformity and hence overall orchard and vineyard performance. Suggested application rates for the use of compost and mulch is provided in Table 2.

Cost considerations

The overwhelming conclusion from our results over almost 10 years is that the use of compost improves returns.

Fertiliser savings are the major immediate gain that growers can make when using compost. Based on least cost fertilisers, the savings detailed in the crop nutrition section, to principally phosphorus, potassium and magnesium requirements, will cover at least 60 per cent of an applied compost cost of \$40/m³.

Based on recent work, percentage increases in yield necessary to cover costs of applying 25 m³/ha of compost at \$40/m³ and allowing for \$20/m³ fertiliser savings are provided in Table 4. The indicated yield increases are within those achieved in vegetable trials at the Medina Research Station.

The current applied cost of compost, suited to use in vegetable production is \$35-45/m³, depending on source, volume and transport requirements. Factors such as increasing fertiliser costs and increasing landfill levies on the disposal of organic wastes are likely to make compost more competitive in future.

Table 4. Percentage increase in yield necessary to cover cost of applying 25 m³/ha of premium grade compost to selected vegetable crops

| Crop | Marketable yield | Unit | Market return \$/unit | | Yield increase to cover cost of compost (%) | |
|----------|------------------|-----------|-----------------------|-------------|---|----------------|
| | | | <i>Low</i> | <i>High</i> | <i>Minimum</i> | <i>Maximum</i> |
| Lettuce | 3,800 | crates/ha | 5.00 | 10.00 | 1.2 | 2.9 |
| Broccoli | 12,000 | kg/ha | 0.75 | 1.00 | 4.6 | 6.1 |
| Carrots | 71,550 | kg/ha | 0.50 | 0.75 | 0.7 | 1.2 |

Further reading

- AS 4454–2003 Australian Standard for Compost, soil conditioners and mulches. Available from SAI Global www.techsheet.com Ph: 1800 699 9277.
- Buchanan M (2002) Compost maturity and nitrogen release characteristics in Central Coast Vegetable production. Californian Integrated Waste Management Board publication (www.ciwmb.ca.gov/Organic_wastes/Publications/).
- Buchanan M, Brinton W, Shields F, West J, Thompson W, Cotton M (2002) The CCQC Compost Maturity Index. In 'Proceedings of Waste and Recycle 2002 Conference' Perth WA, pp. 83-92.
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- Millar PD (2002) Composting: A durable technology for disinfestation of manure, sewage sludge and organic residuals in an era of emerging and re-emerging pathogens. Composting and compost utilisation. International symposium, Columbus, Ohio USA.
- Paulin R (2007) Report on 'North American compost tour – California, Florida and Toronto,' January 2007, 28 pp. Department of Agriculture and Food, Perth WA.
- Paulin R, Wilkinson K (2002) Report on 'Tour of compost production and utilisation in Californian horticulture and on the 'Composting and compost utilisation symposium', Columbus, Ohio, USA, April-May 2002, 18 pp, Department of Agriculture, Perth WA.
- Paulin R, O'Malley P (2004) Economic considerations for compost use in horticulture and implications for compost market development. Waste and Recycle Conference 2004, 21-24 September 2004, Fremantle WA.
- Paulin R, O'Malley P, Wilkinson K, Flavel T (2004) Identifying the benefits of composted soil amendments to vegetable production – Report to Horticulture Australia Ltd, Project VG 990016. CD available from Department of Agriculture and Food, Perth WA.



Appendix: Compost feedstocks - typical C:N, density and structure ratings

| Material | Density (kg/m ³) | Structure rating (1 to 4)* | C:N ratio (xx:1) |
|-----------------------|---------------------------------|-------------------------------|---------------------|
| Bark, hardwood | 534.00 | 2 | 125 |
| Bark, softwood | 415.33 | 2 | 135 |
| Cardboard, dry | 148.33 | 1 | 520 |
| Corn stalks | 124.60 | 1 | 40 |
| Grape, pumice | 712.00 | 2 | 27 |
| Grass/lucerne hay | 109.77 | 1 | 35 |
| Hay, dry bales | 124.60 | 1 | 30 |
| Hay, rough grass | 103.83 | 1 | 95 |
| Hay, round bales | 178.00 | 1 | 25 |
| Hay, grass green | 109.77 | 1 | 46 |
| Olive pumice | 700.00 | 3 | 70 |
| Paper, newsprint | 296.67 | 3 | 400 |
| Peat/moss | 148.33 | 3 | 64 |
| Pine needles | 118.67 | 2 | 110 |
| Pinewood shavings | 356.00 | 1 | 350 |
| Sawdust, dry | 256.32 | 3 | 365 |
| Sawdust, dry hardwood | 237.33 | 3 | 996 |
| Straw, oat | 118.67 | 1 | 120 |
| Straw, wheat, loose | 118.67 | 1 | 120 |
| Trimnings, shrub | 676.40 | 3 | 55 |
| Trimnings, tree | 255.13 | 1 | 30 |
| Woodchips, hard | 415.33 | 2 | 430 |
| Woodchips, soft | 356.00 | 1 | 500 |
| Yard waste | 332.27 | 2 | 44 |

* Structure rating is a measure of the material's porosity where 1 is porous and 4 is very dense.