Composting green waste with other wastes to produce manufactured soil

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Abstract
Manufactured soil for landscaping purposes was produced by composting for 6 weeks (a) municipal green waste alone, (b) green waste amended with 25% v/v poultry manure or (c) green waste immersed in, and then removed from, a mixture of liquid grease trap waste/septage. During composting, temperatures reached 52ºC in green waste alone, 61ºC in poultry manure-amended and 78ºC in grease trap/septage-amended green waste. Following composting, each of the materials was split into (i) 100% compost, (ii) 80% compost plus 20% v/v soil and (iii) 70% compost plus 20% soil plus 10% coal fly ash. Addition of soil, or soil and ash, to composts increased bulk density, reduced total porosity and increased available water holding capacity. Bicarbonate-extractable P, exchangeable NH_4^+ and NO_3^-, EC and basal respiration were all markedly greater in the grease trap/septage-amended than poultry manure-amended or green waste alone treatments. Values for extractable P and EC were considered large enough to be damaging to plant growth and germination index (GI) of watercress was less than 60% for all grease trap/septage composts.

Key Words
Green waste, grease trap waste, compost, available water, available nutrients, microbial activity

Introduction
Municipal green waste consists of a range of materials including tree wood and bark, prunings from young trees and shrubs, dead and green leaves and grass clippings and it originates from both domestic dwellings and municipal parks, gardens and reserves. In most cities in the developed world, green waste is collected separately from other wastes and is mechanically shredded and then composted, either alone or with other organic wastes. It is used in products such as garden mulch, organic soil amendment, garden compost and soilless potting media. However, in Australia, the main use for the composted material is as "manufactured soil" used for field landscaping purposes in place of natural topsoil. Often, inorganic additives (e.g. sand, subsoil, fly ash) are blended with the composted material. Nevertheless, the inorganic component makes up only 10-30% v/v of the final product. The product is considerably cheaper than excavated natural topsoil and is therefore commonly used by landscape contractors.

The exact nature of the ingredients, other than green waste, the ratios at which they are mixed and length of the composting period have been arrived at by trial and error and differ appreciably between contractors. Whilst the above operations are commonplace in Australia, and may well have more widespread application, to date little scientific evaluation of the operations and the products produced has been performed. Indeed, although green waste is commonly composted (Bradshaw *et al*., 1996; Manser and Keeling, 1996) and a number of workers have investigated the properties of the composted material (e.g. Zaccheo *et al*., 2002; Brewer and Sullivan, 2003), there appear to be no reports, other than that of Belyaeva and Haynes (2009), on its use as the basis of the production of manufactured soils. The aim of this study was to compare composting intensity and the properties of manufactured soils produced through composting green waste alone or co-composting it with an easily-decomposable activator material such as poultry manure or grease trap waste/septage. Following initial compost production, the products were amended with 20% topsoil, or 20% topsoil plus 10% coal fly ash (to produce manufactured soil) and allowed to mature.

Materials and methods
Materials and composting
Municipal green waste was collected from Phoenix Power Recyclers, Yatala, Queensland, soon after it had been mechanically shredded. Recently-deposited fly ash was collected from the fly ash disposal lagoon at Tarong Power Station, 80 km west if Brisbane. Poultry manure was collected from a commercial egg producer. Liquid grease trap waste and septic tank waste were collected separately and deposited in a sealed lagoon at Phoenix Power Recyclers. The A and B horizon of a silt loam soil classified as a Clastic Rudosol (Isbell, 2002) was excavated from an unfertilized area under native vegetation. The compost treatments were, (1) 100% green waste (GW), (2) 75% green waste/25% poultry manure v/v (GWP) and (3) green waste

immersed in a liquid mixture of grease trap waste/septage for 6 hours and then removed (GWG). Two hundred litre samples of the mixtures were placed in 250 litre plastic composting bins. The experiment was replicated 3 times. Piles were turned every 7 days in order to ensure adequate O_2 levels inside piles. Temperature was monitored at a depth of 40 cm inside the piles at 0900 h each day. The water content of piles was maintained at 60-70% of their water holding capacity. After 6 weeks of composting each treatment replicate was split into 3: (i) 100% compost (Control), (ii) 80% compost plus 20% v/v soil (S) and (iii) 70% compost plus 20% soil and 10% fly ash v/v/v (SA). The resulting materials were thoroughly mixed and allowed to react and mature for a further 4-week period.

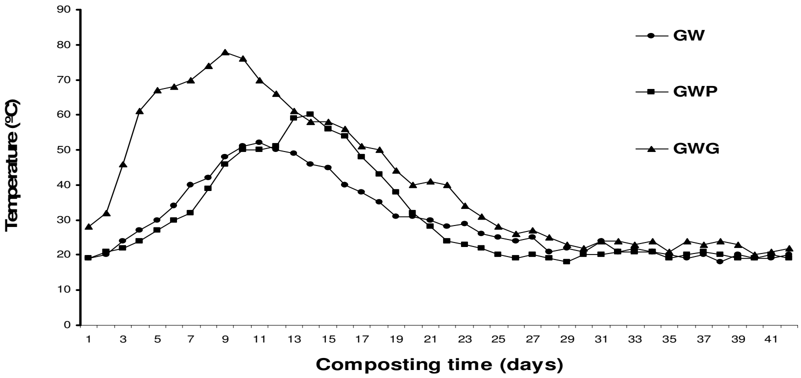

Figure 1. Temperature during composting in composts composed of green waste alone (GW), green waste plus poultry manure (GWP) and green waste plus grease trap waste (GWG).

Compost analyses
Ten subsamples were taken randomly from within each pile. Subsamples were bulked, homogenised and ground to pass a 5mm sieve. A part of each sample was stored at 4ºC for microbial and physical analysis and the rest was air-dried and stored for chemical analysis. Electrical conductivity and pH were analysed in a 1:5 (v/v) water extract using a glass electrode. Extractable mineral N was extracted with 2 M KCl (1:100 ratio for 1 h) followed by colorimetric analysis of NH_4^+ and NO_3^--N. Available P was extracted with 0.5 M $NaHCO_3$ (pH 8.5) (1:100 w/v for 16 h) (Colwell, 1963) and measured colorimetrically. Bulk density was determined on naturally compacted samples, particle density by the pycnometer method and total porosity by difference. Soil water content in samples was determined at -10 and -1500 kPa using a pressure plate apparatus.

A germination test was carried out (in quadruplet) on filter paper in petri dishes. Two ml of aqueous extract (1/10 w/v) from composts was added to dishes. Ten seeds of watercress (Lepidium sativum) were placed on the filter paper and dishes placed in the dark at 28ºC. The germination index percentage with respect to control (distilled water) was determined after 5 days. The control GI value was considered as 100%.

The statistical significance of experimental treatments was determined by Analysis of Variance Analysis using the Minitab Statistical Software Package and differences were calculated at the 5% level using Tukey's test.

Results and discussion

The composition of municipal green waste is typically dominated by shredded wood and bark, with high lignin and tannin contents respectively, and these components are not readily decomposed by microbial activity (Francou *et al*., 2008). In addition, green waste is often left in stockpiles before shredding and/or composting. During these periods, much of the "soft" green waste decomposes thus further contributing to its slow decomposition during subsequent composting. As a result, temperatures during composting of green waste-alone only reached 52ºC for a short period and then declined (Figure 1). In order to initiate a more active phase of intense microbial activity during composting, the addition of a readily decomposable organic material is required. Addition of poultry manure at 25% v/v to green waste was shown here to both prolong the period over which temperatures were elevated as well as raise the temperature attained to 61ºC (Figure 1). The grease trap waste tended to coat the green waste thus offering a large surface area for microbial decomposition during composting (Coker 2006). Lipids are easily degraded under aerobic conditions (Wakelin and Forster 1977) and their high energy content resulted in composting rapidly achieving thermophilic temperatures. Maximum temperature reached was 78ºC (Figure 1).

Table 1. Some physical and chemical properties and germination index in green waste (GW), green waste plus poultry manure (GWP) and green waste plus grease trap waste/septage (GWG) – based composts to which nothing (Control), 20% topsoil (S) or topsoil (20%) plus coal fly ash (10%) (SA) had been added.

Treatment	Bulk density ($m\ m^{-3}$)	Total porosity ($m^3\ m^{-3}$)	Available water ($kg\ m^{-3}$)	EC ($mS\ cm^{-1}$)	Extracable P ($mg\ kg^{-1}$)	Germination index (%)
GW(control)	0.29a [a]	0.83d	133a	1.1b	616b	94bc
GW(S)	0.69d	0.70b	190ab	0.62a	212a	117c
GW(SA)	0.69e	0.66ab	273c	0.61a	183a	119c
GWP(control)	0.35b	0.79c	171a	1.1b	553c	85b
GWP(S)	0.58d	0.71b	258c	0.60a	228a	116c
GWP(SA)	0.69e	0.65ab	299c	0.64a	186a	145d
GWG(control)	0.35c	0.76c	129a	2.8e	2771f	54a
GWG(S)	0.66de	0.68b	174a	1.6d	1250e	57a
GWG(SA)	0.76e	0.64a	225b	1.3c	894d	61a

Means followed by the same letter within a column are not significantly different at $p \leq 0.05$

Composted green waste was characterized by a low bulk density and high total porosity (Table 1). The high macroporosity and relatively low available water holding capacity may limit its use in a field landscaping situation (Belyaeva and Haynes, 2009). The greater intensity of microbial decomposition induced by addition of poultry manure or grease trap waste/septage to green waste tended to result in a greater percentage of small particles being produced and this caused an increase in bulk density and a lowering of total porosity (Table 1). When added to the composted green waste, fine soil material (i.e. originating from a silt loam) and/or coal fly ash partially filled the macropores of the green waste resulting in an increase in bulk density, decrease in total porosity and an increase in percentage mesoporosity and thus available water holding capacity (Table 1). The substantial increases in available water holding capacity that resulted are likely to be of considerable benefit when the material is being used in a field landscaping application, particularly in the Australian context where droughts are common and most cities currently have water-use restrictions in place.

High concentrations of extractable P are a characteristic of green waste composts (Hue *et al*., 1994; Belyaeva and Haynes, 2009) because organic material has insignificant P-sorption capacity and therefore a relatively large proportion of their total P content (e.g. 30-40%) is extractable and potentially bioavailable. Concentrations of extractable P (Table 1) encountered in the GW and GP alone composts (183-616 mg kg^{-1}) are excessive whilst those in the GG compost are extraordinarily high (2771 mg kg^{-1}). These levels may well be harmful to plants, particularly Australian native plants that are adapted to low available P conditions. Handreck and Black (2002), for example, suggested optimum Colwell P levels were < 10mg kg^{-1} for native plants sensitive to P and < 40 mg kg^{-1} for plants moderately sensitive to P. Similarly, soluble salts (EC > 1.3 mS cm^{-1}) were extremely high (Table 1) and large concentrations of NH_4^+ and NO_3^- were also present in the GWG composts. That is, concentrations of NH_4^+-N ranged between 69 and 227 mg kg^{-1} and NO_3^--N between 68 and 80 mg kg^{-1} in GWG composts compared with between 1.9 and 14 mg kg^{-1} for NH_4^+-N and 0.26- 0.68 mg kg^{-1} for NO_3^--N in the other two composts (data not shown). The high levels of salts, P and mineral N probably all contributed to the low GI (< 60%) for the GWG composts. Thus, the high salt, P and N content of the grease trap waste/septage resulted in accumulation of these substances in the GWG compost. Values of GI less than 100% were also recorded for the GW alone and GWP alone composts and these were probably related to high soluble salts (> 1.0 mS cm^{-1}) and high extractable P (> 500 mg kg^{-1}) levels. That amendment of GW and GWP composts with soil or soil plus ash resulted in GI values > 100% demonstrates the importance of such amendment with regard to producing a suitable substrate for plant germination and growth. Such amendment lowers EC and extractable P (Table 1) by dilution and in the case of P also by adsorption. That is, both soil and fly ash contain mineral surfaces (e.g. Al and Fe oxides and aluminosilicates) that can specifically adsorb phosphate.

Conclusions

Green waste is an effective adsorbent material for grease trap waste/septage and the material composts rapidly at thermophilic temperatures. The resulting compost does, however, contain excessive levels of extractable P, high soluble salts and mineral N levels. There seems scope to dilute the grease trap/septage-amended compost with unamended green waste compost in order to lower soluble salts, extractable P and mineral N in the saleable product. Addition of inorganic materials such as subsoil or fly ash to composted green waste has several important positive effects including increasing available water holding capacity and reducing excessive concentrations of soluble salts and P that may have accumulated.

References

Belyaeva ON, Haynes RJ (2009) Chemical, microbial and physical properties of manufactured soils produced by co-composting municipal green waste with coal fly ash. *Bioresource Technology* **100**, 5203-5209.

Bradshaw J, Lehmann TR, Ragsdale J, Snow C (1996) Recycling Yard Trash: Best Management Practices Manual for Florida. (Florida Organics Recyclers Association, Tallahassee, Florida).

Brewer LJ, Sullivan DM (2003) Maturity and stability evaluation of composted yard trimmings. *Compost Science and Utilization* **11**, 96-112.

Coker C (2006) Composting grease trap wastes. *BioCycle* **47**, 27-30.

Colwell JD (1963) The estimation of the phosphorus fertilizer requirements of wheat in southern New South Wales by soil analysis. *Australian Journal of Experimental Agriculture and Animal Husbandry* **3**, 190-198.

Francou C, Lineres M, Derenne S, Le Villio-Poitrenaud M, Houot S (2008) Influence of green waste, biowaste and paper-cardboard initial ratios on organic matter transformations during composting. *Bioresource Technology* **99**, 8926-8934.

Handreck KA, Black ND (2002) Growing Media for Ornamental Plants and Turf. (NSW University Press, Randwick).

Hue NV, Ikawa H, Silva JA (1994) Increasing plant-available phosphorus in an Ultisol with a yard-waste compost. *Communications in Soil Science and Plant Analysis* **25**, 3291-3303.

Isbell RF (2002) The Australian soil classification. (CSIRO Publishing, Collingwood, Victoria).

Manser AGR, Keeling AA (1996) Practical Handbook of Processing and Recycling of Municipal Waste. (CRC Press, Boca Raton).

Wakelin NG, Forster CF (1977) An investigation into microbial removal of fats, oils and greases. *Bioresource Technology* **59**, 37-43.

Zaccheo P, Ricca G, Crippa L (2002) Organic matter characterization of composts from different feedstocks. *Compost Science and Utilization* **10**, 29-38.

Zucconi F, Monaco A, Forte M, De Bertoldi M (1985) Phytotoxins during the stabilization of organic matter. In: ‘Composting of Agricultural and Other Wastes’. (Ed JKR Gasser), pp 73-85. Elsevier, London.