Available online at www.sciencedirect.com
ScienceDirect
European Journal of Soil Biology 43 (2007) S316–S319
EUROPEAN JOURNAL OF SOIL BIOLOGY
http://www.elsevier.com/locate/ejsobi

Original article

Evaluating the growth characteristics of lettuce in vermicompost and green waste compost

Muhammad Ali [a,*], Anthony J. Griffiths [a], Keith P. Williams [a], Davey L. Jones [b]

[a] *School of Engineering, Cardiff University, The Queen's Building, Parade, Cardiff CF24 0YF, UK*
[b] *School of Environment and Natural Resources, University of Wales, Bangor, Deiniol Road, Bangor, Gwynedd LL57 2UW, UK*

Available online 1 October 2007

Abstract

Vermicompost was produced from a green waste compost feedstock and assessed for its potential use in a high value horticultural market. Replicated plant growth trials were undertaken with lettuce using pure worm cast (vermicompost), green waste-derived compost and mixtures of the two, i.e. 50/50 (v/v) and 20/80 (v/v) of worm casts and green waste feedstock. Results showed that plant biomass production was optimal with a 20/80 (v/v) compost blend, whilst pure worm cast and green waste compost yielded poor growth. Leaf chlorophyll content indicated that pure worm cast inhibited plant growth and depressed N content, whereas plant grown with the other treatments contained similar amounts of chlorophyll. In general, the vermicomposting process did not result in an increased availability of nutrients or potentially toxic elements, the only exception being Zn.

Keywords: Vermicomposting; Green waste-derived compost; Cast material; Lettuce; Nutrients

1. Introduction

Studies conducted on vermicomposts have shown that the product is a well stabilised, aesthetically pleasing, finely divided peat-like material with excellent structure, porosity, aeration, drainage and enhanced moisture holding capacity [6,8] with the capability of enhancing plant growth. For example, it has been reported by Atiyeh et al. [2,3,4] that the best response occurs when worm casts comprise only 10–20% of the volume of the mix and poor plant growth was observed when the proportion was above 60% [3,10]. Few studies other than those by Frederickson et al. [8] have been carried out to investigate the use of green waste compost as the feed material during vermicomposting.

Replicated growth trials were undertaken in the present study with lettuce (*Lactuca sativa* L.) using pure worm casts, green waste compost and mixtures of the two to determine the extent of growth enhancement gained through the vermicomposting process.

2. Materials and methods

The vermicompost (VC) was derived by using mature (18 months, <10 mm) green waste-derived windrowed compost (FS) as feedstock to the worm reactors that were manufactured from timber surrounds and steel mesh as the base [1]. Each bed measured 2.4 × 1.2 × 0.43 m and the compost rested on a mesh with

* Corresponding author. Fax: +44 29 2087439.
E-mail address: alim1@cf.ac.uk (M. Ali).

1164-5563/$ - see front matter
doi:10.1016/j.ejsobi.2007.08.045

effective opening size of approximately 6 mm. The typical moisture content of the FS was about 400 g kg^{-1} and this was adjusted to 600 ± 20 g kg^{-1} using tap water. Earthworms (*Dendrobaena veneta*) were added to a density of 7 kg m^{-2} and were fed on a weekly basis for a total period of 18 weeks. The two materials, FS and VC, were used in the growth trials as single substrates and also in 50/50 and 20/80 (VC/FS) mixtures on a volume basis. For the purposes of this study, FS was considered as the control. Opaque 1l plastic pots were filled with each substrate and five seeds were sown at a depth of approximately 2 cm. Three replicate pots were used for each medium and were kept in a glasshouse under artificial lights at 20 ± 2 °C and watering to their water holding capacities was carried out three times weekly. After germination, only the single best seedling was allowed to grow to maturity for 49 days. Plant fresh weights were determined at harvest and dry weights were subsequently determined after oven drying at 80 °C overnight. Leaf chlorophyll content, an indication of N uptake by the plants, was determined using the Soil Plant Association Development, SPAD 502 meter (Minolta Corporation, Japan). Phosphorus, potassium and potentially toxic element concentrations were determined by digesting 0.1 g of air-dried composts samples in a microwave (Anton Paar 3000) using aqua regia. To assess plant available nutrients and heavy metals, each compost type (10 g) was shaken (200 rev min^{-1}) in a Stuart SSL1 orbital shaker with 30 ml of distilled water for 1 h. The extracts were then centrifuged (Sigma 6K15) at 4000 rev min^{-1} for 15 min. All liquids for analysis by inductively coupled plasma optical emission spectrophotometry (Perkin Elmer, Optima 2100 DV ICP-OES) were first filtered at 0.2 μm. Nitrogen concentrations were determined on solids by the high temperature process (LECO 2000 CHN analyser). Statistical analysis (ANOVA with Tukey pairwise comparison) was undertaken with Minitab v14 (Minitab Inc., State College, PA, USA) with significant differences identified at $P < 0.05$ level.

3. Results and discussion

The fresh weights of the plants (Fig. 1) grown on the mixed substrates are significantly higher than those

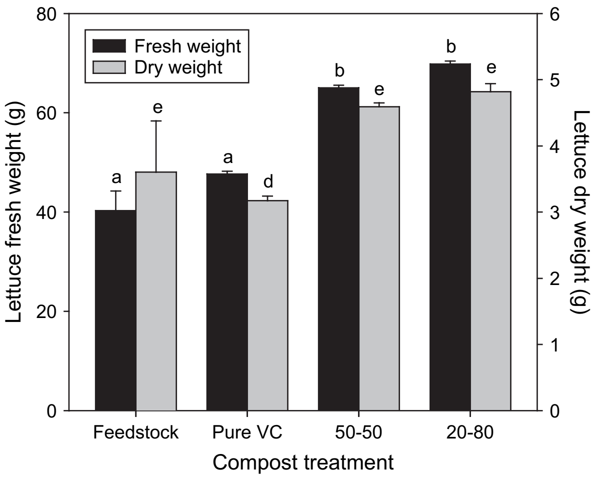

Fig. 1. Fresh and dry weight of lettuce plants. Columns with different letters (a and b for fresh weight, d and e for dry weight) are significantly different from each other at $P < 0.05$.

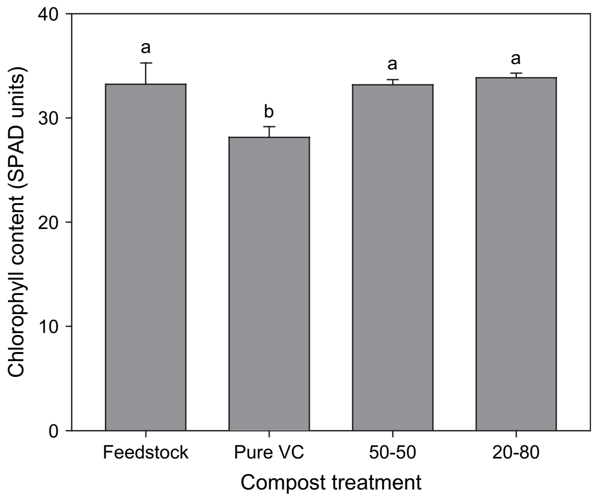

Fig. 2. Leaf chlorophyll content in lettuce plants. Columns with different letters (a and b) are significantly different from each other at $P < 0.05$.

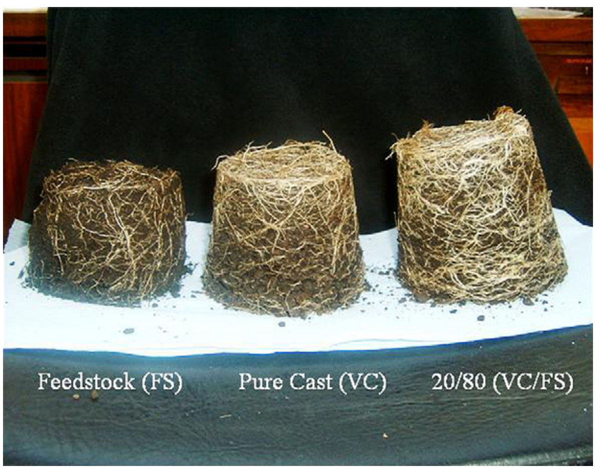

Fig. 3. A visual comparison of lettuce root structure in the different compost treatments. The photographs are representative of at least three replicate plants.

Table 1
Nutrient contents of growth media

Compost treatment	Total nutrients ($g\ kg^{-1}$)			Plant available nutrients ($mg\ kg^{-1}$)[a]	
	N	P	K	P	K
Feedstock (FS)	16.83 ± 0.53	3.6 ± 0.01	11.4 ± 0.17	66 ± 4	7359 ± 326
Pure cast (VC)	15.30 ± 0.36	3.1 ± 0.08	9.7 ± 0.21	56 ± 4	5634 ± 177
50/50 (VC/FS)	15.74 ± 0.60	3.4 ± 0.20	10.3 ± 0.43	48 ± 4	6150 ± 521
20/80 (VC/FS)	16.46 ± 0.65	2.8 ± 0.12	9.8 ± 0.40	28 ± 1	5157 ± 152

Values represent mean ± standard error of the mean ($n = 3$). All values are on dry basis.
[a] Instrument problem with detection of water soluble N.

grown on VC and FS. Similarly, Fig. 1 shows that the dry weights of plants grown on VC alone were the lowest amongst the four growth mediums. Leaf chlorophyll contents (Fig. 2) were significantly lower for the plants grown on pure VC. Atiyeh et al. [2,3] observed similar differences during marigold and greenhouse tomato seedling growths. Fig. 3 illustrates the contents of the three pots after they were carefully emptied onto the laboratory bench. It can be clearly seen that roots of plants grown in the 20/80 (v/v) mix exhibited a well-developed structure when compared in particular to the root structure of FS. Nutrient contents expressed as total and water-soluble concentrations in the growth media are presented in Table 1. These must be considered alongside the mass reduction of approximately 20% that occurred, as the original compost was converted to vermicompost [1]. It would be expected that the concentrations in VC would increase compared to FS, if there was a conservation of each element. This increase in concentration was not observed and cannot be easily explained other than by analytical error and difficulties in sampling these heterogeneous materials. What is clear is that, the availability of nutrients is almost similar in each of the substrate. The lowest concentrations of available phosphorus and potassium, in particular occurred in the 20/80 (VC/FS) mixture as shown in Table 1 and it is interesting to note that this is related to the highest plant biomass and leaf chlorophyll as shown in Figs. 1 and 2, respectively. Thus the enhanced growth and root development are not simply the functions of nutrient availability. It can be observed from Table 2, that of all the potentially toxic elements, Zn is present in the highest concentrations for all mediums. However, that concentration remains below the limit set by the Composting Association, UK, Standards under the BSI Scheme designated as PAS 100:2005. For all the potentially toxic elements, the availability, i.e. water solubility is very low. The most soluble is Zn, with only about 0.5% of the total being available. For the Zn alone there is some evidence of increased availability in the vermicompost compared to FS. For example, the feedstock contained 0.37 $mg\ kg^{-1}$ of available Zn, when compared to 3.36 $mg\ kg^{-1}$ observed for pure vermicompost.

Recent research on the plant growth improvements due to application of worm casts [2,3] has attributed the enhancements to a range of parameters such as humic acid content [4,5], plant growth regulators and/or symbiotic microbes [9,10] growth hormones or hormones that had been adsorbed on humic acids during vermicomposting [7]. The present work adds support to the contributions of parameters other than the nutrient content and again demonstrates that the low applications are the most beneficial. Clearly, further work is required to determine the exact mechanisms behind the improved growth.

Table 2
Potentially toxic elements (PTEs) in the growth media

Compost treatment	Total PTEs ($mg\ kg^{-1}$)			Plant available PTEs ($mg\ kg^{-1}$)		
	Cr	Zn	Ni	Cr	Zn	Ni
Feedstock (FS)	93 ± 23	238 ± 17	38 ± 04	ND	0.33 ± 0.05	0.05 ± 0.01
Pure cast (VC)	66 ± 09	296 ± 12	35 ± 01	ND	3.36 ± 0.91	0.04 ± 0.00
50/50 (VC/FS)	58 ± 08	289 ± 29	34 ± 02	ND	1.28 ± 0.43	0.03 ± 0.01
20/80 (VC/FS)	58 ± 09	261 ± 17	33 ± 01	ND	0.87 ± 0.04	0.01 ± 0.00
PAS100[a]	<100	<400	<50	Not available		

Values represent mean ± standard error of the mean ($n = 3$). All values are on dry basis.
The Composting Association, UK, Standards. ND indicates not detected.
[a] Publicity available specification BSI-PAS100:2005 for composted material.

4. Conclusions

The highest plant fresh and dry weights were observed for the two compost mixtures, i.e. 50/50 and 20/80 (VC/FS). Leaf chlorophyll contents were similar for all plants other than those grown on pure vermicompost. Of all the heavy metals examined, only zinc showed an increase in plant availability after the vermicomposting process. The enhanced plant weights were independent of the nutrient contents of the substrates and to some extent the root development. The relative importance of other factors such as worm cast's humic acid contents, plant growth regulators, hormones and symbiotic bacterial activity requires further investigation.

References

[1] M. Ali, A.J. Griffiths, K.P. Williams, D.L. Jones, Vermicomposting-enhancing the quality of compost derived from green waste 21st International Conference on Solid Waste Technology and Management, Philadelphia, USA, Journal of Solid Waste Technology and Management (2006) 667–680.

[2] R.M. Atiyeh, N.Q. Arancon, C.A. Edwards, J.D. Metzger, W. Shuster, Effect of vermicomposts and composts on plant growth in horticulture container media and soil, Pedobiologia 44 (2000) 579–590.

[3] R.M. Atiyeh, N.Q. Arancon, C.A. Edwards, J.D. Metzger, Influence of earthworms-processed pig manure on the growth and yield of greenhouse tomatoes, Bioresource Technology 75 (2000) 175–180.

[4] R.M. Atiyeh, N.Q. Arancon, C.A. Edwards, J.D. Metzger, Influence of earthworms-processed pig manure on the growth and productivity of marigolds, Bioresource Technology 81 (2002) 103–108.

[5] N.Q. Arancon, C.A. Edwards, R.M. Atiyeh, J.D. Metzger, Effects of vermicompost produced from food waste on the growth and yield of greenhouse peppers, Bioresource Technology 93 (2004) 139–144.

[6] C.A. Edwards, I. Burrows, The potential of earthworm composts as plant growth media, earthworms in waste and environmental management, in: C.A. Edwards, E. Neuhauser (Eds.), Earthworms in Waste Management, SPB Academic Press, The Hague, Netherlands, 1988, pp. 21–32.

[7] C.A. Edwards, N.Q. Arancon, S. Graytak, Effects of vermicompost teas on plant growth and disease, Biocycle 47 (5) (2006) 28–31.

[8] J. Frederickson, K.R. Butt, M.R. Morris, C. Daniel, Combining vermiculture with green waste composting system, Soil Biology & Biochemistry 29 (3/4) (1997) 725–730.

[9] R.D. Kale, B.C. Mallesh, K. Bano, D.J. Bagyaraj, Influence of vermicompost applications on the available macro nutrients and selected microbial population in a paddy field, Soil Biology & Biochemistry 24 (12) (1992) 1317–1320.

[10] S. Subler, C. Edwards, J. Metzger, Comparing vermicomposts and composts (ABI/INFORM Global), Biocycle 39 (7) (1998) 63–65.