Journal of Applied Horticulture, 8(2): 165-169, July-December, 2006

Technical and economic aspects of utilizing fibrous wool composts in horticulture

K.C. Das[1]*, P.A. Annis[2], E.W. Tollner[1] and S. Dudka[3]

[1] *Department of Biological and Agricultural Engineering;* [2] *Department of Textiles, Merchandising and Interior;* [3] *Department of Crop and Soil Sciences, The University of Georgia, Athens, GA 30602-4435, USA. *E-mail: kdas@engr.uga.edu*

Abstract

Composts produced from a mixture of fibrous wool by-products and other components (*e.g.*, wood-shavings, cotton-gin trash, yard waste, biosolids, *etc.*) have a high concentration of nitrogen and low concentrations of regulated trace elements. Some have low soluble salts content and have slightly acidic to neutral pH. These composts met standards of the US EPA of an exceptional quality product and were successfully used to grow ornamental crops in a greenhouse and to establish turfgrass from seeds. Market research showed that the turfgrass industry and retail garden centers would be the largest and most profitable markets for fibrous wool-based composts and potting mixes. Cost-volume-profit analysis (CVP) indicated that production and sale of about 17,200 tonnes per year of the compost product would be a break-even point in units for a hypothetical compost production and marketing business. Since composting is also a waste management operation, revenues from accepting waste (tipping fees) does improve business profitability.

Key words: Bioconversion, wool, composting, wood wastes, economic analysis.

Introduction

The retail sector, tree farms, nurseries, greenhouses and turf applications are known to be highly profitable market segments for compost use within the horticultural industry (Tyler, 1996; Walker *et al.*, 2006). In addition, it is known that sod production is a large volume market for compost utilization (Tyler, 1996). Retail markets demand high quality potting mixes and soil amendments to grow container plants and ornamentals. Likewise, commercial greenhouses and nurseries also demand consistent potting mixes/soil amendments for their field work. Previous work has shown that nutrients from compost or its extracts can significantly benefit ornamentals nurseries. For example, Jarecki *et al.* (2005) found that marigolds responded well to compost leachate in a hydroponic growth experiment.

Homeowners and business customers value compost products that are consistent and stable and have the right combination of physical and chemical properties (Composting Council, 1995). Although most sod is grown in the field, some sod producers are interested in growing sod on plastic sheets (Decker, 1989), which entails spreading a layer of organic substrate over plastic and growing grass on it. The crop is harvested by rolling up the sod from the plastic. The convenience of this approach is expected to make this an increasingly popular method of sod production.

Tyler (1996) reported that compost sale prices were highest at urban retail garden centers (US\$17.6 to 27.5 tonne^{-1}; 16 to 25 tonne^{-1}) and when used in turf applications (US\$17.6 to 22 tonne^{-1}). All other low-volume, high-dollar markets had reported sale prices in the range of \$4.4 to 17.6 tonne^{-1}. These reported prices suggest that highest profitability for compost producers may occur at retail and turf applications. Therefore, our work on fibrous wool compost products focused on developing potting mixes for growing ornamentals (targeting retail garden centers) and soil amendments for turfgrass establishment.

The objective of this work was to evaluate through greenhouse experiments, the suitability of using fibrous wool-based composts as components of potting mixes to grow ornamental pansies (*Viola wittrakiana* L.) and marigolds (*Tagetes erecta* L.) and to grow turfgrass. In addition the economic feasibility of this product was evaluated through proforma analysis.

Materials and methods

Description of composts and their production: The composts used in this study were made as part of a project to develop useable products from organic waste streams generated around Laurens County, Georgia, USA (Das *et al.*, 1997). The waste streams relevant to this study consisted of wool fiber wastes from a wool fabric manufacturing plant, cotton gin trash from a cotton gin, wood shavings from a lumber yard, yard trimmings from municipal collections, and dewatered biosolids from a municipal wastewater treatment plant using the activated sludge treatment process. Five wool composts blends were made with combinations of wool compost and other potting soil amendments such as pine bark, perlite, and vermiculite. Composts were made either in laboratory scale composting systems (W1 and W2) or in field scale windrows (W3, W4 and W5) using wool fiber waste and agricultural or municipal wastes mentioned earlier.

The individual mixes used in the laboratory are shown in Table 1 and were wool and cotton gin trash at 33 and 67% (w/w, as received) in W1 and wool and wood shavings at 30 and 70% for W2 (Das *et al.*, 1997). Compost mixes used in the field scale windrows included wool, yard trimming and biosolids at 3, 60 and 37% (w/w, as received) in W3, wool and yard trimmings at 4.5 and 95.5% in W4, and wool and cotton gin trash 10.4 and 89.6% in W5 (Das *et al.*, 2000).

Mixes W1 and W2 were composted in research compost vessels as described by Das *et al.* (1997). The compost vessels were stainless steel containers with a diameter of 38.1 cm, depth of 49.5 cm and a volume of 56.8 L. The vessels were insulated with 7.6 cm of foam insulation to minimize conductive heat loss thereby simulating an environment within a large compost pile. Temperature of the material in the vessel was monitored using T-type thermocouples and vessels were aerated using a temperature feedback control with an adjustable set point. When the compost temperature exceeded the set point, air was continuously introduced to the vessel at a rate of 40.8 m^3 day^{-1}. When the temperature of the compost was below the set point, air was introduced intermittently based on a timer providing aeration for 30 seconds in every 20 minutes. The resulting effective aeration of 1.02 m^3 day^{-1} was designed to provide sufficient oxygen (>6% residual oxygen) to maintain aerobic microbial growth. The composting continued in the vessels for approximately four weeks, and the materials were removed and allowed to cure (at room temperature with no forced aeration) for a period of over 9 months before using in this study.

Table 1. Mixes used in developing the composts used in greenhouse study

Sample	Components in the mixes and percentage by weight as received	Method of compost preparation
W1	33 Wool + 67 Cotton gin trash	Laboratory reactors
W2	30 Wool + 70 Wood shavings	Laboratory reactors
W3	3 Wool + 60 Yard waste + 37 Biosolids	Field windrows
W4	4.5 Wool + 95.5 Yard waste	Field windrows
W5	10.4 Wool + 89.6 Cotton gin trash	Field windrows

Field treatments were placed in windrows, which ranged in weight from 9.5 to 33.7 tons. A tractor-pulled windrow turner (Aeromaster PT120, Midwest Biosystems Inc., Illinois USA) was used to homogenize the materials in the windrow. At the end of two weeks, water was added using a soaker hose assembly that provided water at a rate of 37 L min^{-1} (9.4 gal min^{-1}) to maintain moisture content of approximately 50%. The composting process continued for 96 days of active management.

Ornamental plant establishment: Wool composts W1, W2 and W3 were each blended with a base mix (containing equal parts by volume of pine bark, perlite, and vermiculite) at 25, 50 and 67% (v/v) inclusion and the resulting potting mixes were evaluated for growing pansies in a completely randomized design with five replicates per treatment. Data collected were analyzed using ANOVA and where applicable comparison of means was conducted using the Duncan's Multiple Range test. In a separate experiment with similar experimental design, marigold plants were grown in pots containing a mix of 25% (v/v) of W5 wool compost and 75% of the base mix. A commercially available Fafard 3B potting mix (blend of milled pine bark, sphagnum peat moss, and perlite) was used as a reference or control potting mix to compare the performance of the treatments. Plant seedlings used were approximately 51 to 76 mm tall (2 to 3 inches) and were obtained from a local garden center. All pots were watered with tap water once a day or to field capacity for optimal moisture content. No fertilizer was used on the wool potting mix during the course of the experiment since the mixes' ability to satisfy plant nutrient requirements without using external sources of nutrients was being tested. The experiments were conducted for six weeks. At the end of this time period plant growth observations such as biomass yield, number of buds per pot, and number of open buds were made and above ground plant biomass was collected to evaluate total dry biomass per pot.

Turfgrass establishment: Soil in the turfgrass test plots (1 x 1 m) was amended with a 51-mm (2-inch) layer of the W4 and W5 composts, respectively. Each treatment was replicated in a completely randomized design as described earlier and soil amended with straw mulch and NPK fertilizer (300 kg/ha of 10-10-10 fertilizer) was used as a control. The surface-applied composts were tilled to a soil depth of approximately 100 to 125 mm (4 to 5 inches) and then a 1:1:1 mixture of Bermuda grass (*Cynodon dactylon* (L.) Pers.), perennial ryegrass (*Lolium perenne* L.), and annual ryegrass (*Lolium multiflorum* Lam.) was planted at a sowing rate equivalent to 200 kg ha^{-1}. After six weeks of growth, the grass was clipped at about 25 mm (1 inch) above the soil level. The collected samples were dried in a forced air oven (70°C; 72 h) and weighed to obtain dry mass per plot.

Sample analysis: Dried and homogenized samples (1 g) of composts were digested in three replicates in open vessels with concentrated HNO_3. The resulting digests were filtered through Whatman 42 filters, adjusted to 100 mL volume, and diluted 10 times prior to instrumental analysis. Compositions of regulated elements (As, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Se and Zn) were analyzed by Inductively Coupled Plasma-Mass Spectroscopy (ICP-MS). The resulting measurements are regarded as total compositions in the tested materials. Samples of standard reference materials (SRM l570a and 2709) were included in analytical batches to check the accuracy of the analytical method used. Duplicate samples (approximately 10% of all samples) were used to check precision. Total N in composts were obtained by the combustion of a dry sample in a LECO 2000 CNS analyzer. The pH and soluble salt content of composts were determined by using the standard methods typically used in soil science (Sparks, 1996).

Market research and financial analysis: Market research involved direct interview and phone survey of over 50 retail garden stores located around urban centers in Georgia (retail sales census). Demand for compost products and selling prices were obtained from vendors and in some cases internet sites of commercial establishments. Data collected included quantity of different types of potting media and composts sold and their prices. Projected demands in similar urban areas statewide were estimated by multiplying the compost use per capita from sampled areas by known population densities at other urban locations.

The financial analysis included preparation of pro-forma income statements for a hypothetical compost factory and cost-volume-profit (CVP) analysis. CVP analysis (also known as break-even analysis) is commonly used to determine the effect of changes in a company's selling prices, costs, and volume on its profit in the short term (Homgren *et al.*, 1999). Reliable CVP analysis requires a separation of the total costs into variable and fixed costs. Fixed costs remain constant over some relevant range of output and are time related costs rather than volume related costs. In contrast, variable costs vary directly with changes in volume of output. Cost data used were adopted from Tyler (1996) and Das *et al*. (2001) for the composting side of the business. Prevailing tipping fees were obtained from the Georgia Department of Community Affairs' Solid Waste Report.

Table 2. Composition (mg kg^{-1} dry wt.) of regulated metals in the indicated composts and a commercial mix

Sample[1]	As	Cd	Cr	Cu	Hg	Mo	Ni	Pb	Se	Zn
W1	1.7	0.4	24.4	46	<0.1	2.3	5.0	0.6	20.7	182
W2	1.5	0.3	8.5	20	<0.1	0.6	0.2	0.6	12.4	99
W3	1.4	0.1	7.6	8	<0.1	0.4	0.2	0.6	5.2	45
W4	13.5	0.3	30.0	114.5	0.8	2.5	8.3	7.0	5.5	224
W5	13.9	0.2	19.6	99.3	0.1	2.3	5.9	8.8	4.2	218
Control[2]	0.4	1.1	344	16	0.1	0.8	45	1.5	0.1	67
US EPA[3]	41	39	1200	1500	17	18	420	300	36	2800

[1] W1 (30% wool, 70% wood shaving, w/w, as received), W2 (33% wool, 67% cotton gin trash), W3 (3% wool, 60% yard trimmings, 37% biosolids), W4 (4.5% wool, 95.5% yard trimmings), and W5 (10.4% wool, 89.6% cotton gin trash).
[2] Commercial potting mix.
[3] Environmental protection agency's published limits. Source U.S. EPA (1993).

Results and discussion

Individual pH values of the composts measured at the end of composting were 6.6, 7.2, 7.8, 7.8, and 7.8 for W1, W2, W3, W4, and W5, respectively. Compost W4 and W5 had high salt contents of 3.0 and 2.7 dS m^{-1}, respectively, suggesting potential concern when used with soluble salt sensitive plants (Composting Council, 1995). Salt contents of W1, W2 and W3 were found to be 1.1, 0.9, and 1.8 dS m^{-1}, respectively. Nitrogen (N) contents for the five composts were 3.7, 7.5, 1.5, 1.8, and 1.8% for W1, W2, W3, W4, and W5, respectively. The high concentration of total N seen in W1 and W2 is attributed to the high fraction of wool in these mixtures. The wool itself had a N content of 8.6% as a result of being largely keratin protein. Although high in N, this may not necessarily be an excellent fertilizer because the release of this N is expected to be very slow because of the recalcitrance of the wool to biodegradation.

Amounts of regulated trace elements in the composts and the control potting mix were below the regulatory limits established by the US EPA (Table 2). Since properly composted organic materials are class A products as defined by the US EPA, and because the composts and (compost-based) potting mixes have acceptably low metal concentrations, they can be used and distributed without restrictions.

Greenhouse experiments: The mixes with the higher percentages of composts produced bigger plants of pansies that had better foliage and flower quality than the control and the tested mixes with lower proportions of compost (Table 3). Visual evaluation of plant growth and appearance and biomass yield indicated that W1 was the best performing compost. Plant yield measurements showed that the mix containing 67% of W1 produced significantly higher (1.5 times more) biomass than the control treatments. The better performance of the mixes with more compost could be a result of higher N and trace element concentrations (Table 2).

The fertilized control produced larger plant biomass as a result of the easy availability of nutrients but had fewer open flowers than the W5 treatment (Table 4). Marigolds grew and developed well in the W5 potting mix containing 25% wool compost. Relative to the control mix with no fertilizer, the W5 mix produced about 10% bigger biomass of healthy and attractive plants (Table 4). In addition, the marigolds in the W5 mix had a higher percentage of open flowers than the control treatment. Visual evaluation indicated that marigolds grown in the W5 treatments were more vigorous and had more blooms than did the controls. An additional benefit of using the W5 mix instead of a commercial mix is the potential cost savings from growing plants without fertilizer addition.

Table 3. Yield of pansies in three compost types and three expanded mix levels

Test Compost	Expanding mix : Compost	Biomass yield (g pot^{-1})
W1	3:1	8
W2	3:1	6
W3	3:1	4
W1	1:1	8
W2	1:1	6
W3	1:1	4
W1	1:2	9
W2	1:2	8
W3	1:2	7.5
Control	1:2	6

Note: Expanding mix or base mix contained pine bark, perlite, and vermiculite and was used as the base medium for incorporating the compost.

Table 4. Growth response of marigolds to various potting mixes

Treatment	Marigolds[1]		
	Dry biomass (g pot^{-1})	Number total buds per pot	Number open buds per pot
W5 (25%)[2]	9.4[ab]	36[a]	12[a]
Control[3]	8.4[a]	36[a]	6[b]
Control[3] +NPK	12.5[b]	43[b]	9[ab]

[1] Values that superscripted with different letters are significantly different at P<0.05.
[2] Wool compost + base mix in a ratio of 1:3.
[3] Commercial potting mix.

Turfgrass establishment: Both wool compost treatments produced significantly higher biomass than the control (Table 5), confirming the beneficial effect of the nutrients and organic properties brought by the compost. The grass grown in the W4 and W5 treatments established a dense, uniform, and healthy-looking cover. Growth of the control plants was not as uniform as those growing in the wool compost treatments.

Table 5. Growth response of the 1:1:1 grass mixture to wool compost applications

Treatment	Dry biomass (g plot^{-1})[1]
W4	160.1[a]
W5	155.1[a]
Control[2] + NPK	116.1[b]

[1] Values that superscripted with different letters are significantly different at P<0.05.
[2] Commercial potting mix.

Market research and financial analysis: Projections calculated from retail sales census indicate that the market size in Georgia for potting mixes and soil amendments is approximately 450,000 tons year^{-1} (Table 6). Georgia is a state in the southeast United States with warm temperate climate. The estimated population in Georgia in 2005 was 9.07 million with approximately 70%

living in urban areas (US Census Bureau, 2006). There were also an estimated 3.7 million homes in the state. Assuming 50% of the compost demand in the state goes to commercial uses and 50% to residential, the market size translates to approximately 80 kg home^{-1} yr^{-1} or 30 kg capita^{-1} yr^{-1}.

In order to maximize returns, compost products could be offered at the retail level as potting mixes and soil amendments targeting several different markets. The markets for organic by-products include the following: (i) retail markets (garden centers); (ii) sod producers and turf industries; (iii) landscaping industries; (iv) greenhouses and nurseries; and (v) topsoil blenders (Table 6). To minimize transportation costs of bulk sale product, it is recommended that the marketing effort focus on customers within 30-miles of a compost facility in an urban area. The retail market, however, does not have to be limited to the vicinity of a compost factory; once the product is bagged, it can be shipped distances farther than 30-miles and still produce a profit. Expanding markets over the 30-mile radius can also be profitable in high profit margin markets such as golf courses.

Table 6. Estimated markets for compost products in Georgia

Market	Tons per year
Sod production and turf	270,923
Garden centers	113,530
Landscapers	36,123
Topsoil blenders	20,642
Nursery and Greenhouse operators	12,901
Total	454,119

A composting business is different from other businesses in the way that it serves two sets of customers: (i) inflow customers who require disposal of their solid waste (*e.g.*, fibrous wool processing waste, biosolids, cotton gin trash, *etc.*) and (ii) outflow customers who buy compost products. As a result of waste management functions (inflow), a composting operation can be paid to take raw materials. The projected operating income for a compost factory is based on an assumption that 20,000 tons of final products can be sold at a weighted average price of \$25 tonne^{-1}, generating manufacturing revenue of \$500,000 (Table 7). Typical costs for compost production indicate that total capital and operating costs (for yard trimming composting) range between \$9 and 28 tonne^{-1} depending on amount of grinding, duration of composting and location of facility (Steuteville, 1996). In our analysis, we assumed a production cost of \$18.5 tonne^{-1} which is an average value within the range reported in the literature. The sale price of \$25 was arrived based on selling 90% of production as bulk product at \$12 tonne^{-1} and 10% as bagged product at \$150 tonne^{-1} (\$0.15 kg^{-1} or \$2.7 for a 40-lb bag). The weighted average price, at sales levels of 20,000 tons of the product per year, results in an operating income of \$20,000. Adding inflow revenue from tipping fee for waste material processing would further increase earnings before income taxes to \$286,667. Assuming an effective tax rate of 35%, the net income would be \$186,337 (Table 7). Changing both the sale price, cost of operations, and/or the tipping fee would affect the bottom line of a composting business. If the tipping fee were increased to \$15 tonne^{-1}, which is not an unrealistically high price, and the (weighted) average sale price dropped to \$20 ton^{-1}, there would be an operating loss of \$80,000, but net income, resulting from both sides of the business, would still be around \$201,500 (Table 7). If operating costs increased by up to 55% at sales of 20,000 tons, the business would still be profitable, provided revenues from both sides are included. For example, if the operating costs were higher by about 10% the net income (from both sides of the business) would be about \$232,000. The increase in operating costs, especially selling and marketing costs, is very likely if the products are to be introduced successfully in new and undeveloped markets.

Table 7. Pro forma income statement of composting business Wool Waste Composting Company, Income statement for the year ended December 31, 2006 (value in US \$)

Items	Case I	Case II
Sales Revenue	500,000[a]	400,000[a]
Cost of goods sold – manufacturing and interest on capital	370,000[b]	370,000[b]
Gross income	130000	30000
Operating expenses		
Selling & marketing	60000	60000
Administrative & general	50000	50000
Total operating expenses	110000	110000
Operating income	20000	80,000
Other revenues and gains		
Tipping revenues	266,667[c]	390,000[c]
Earnings before income taxes	286667	310000
Income taxes	100,333[d]	108,500[d]
Net income	186333	201500
Earnings per share	1.86[e]	2.02[e]

[a] Assuming sale of 20,000 tonnes of the product at a weighted average price of US\$25 and US\$20per tonne, for case I and case II, respectively.

[b] The cost of operating a compost facility is estimated at \$18.5 per tonne, which is the median in the range reported by Steuteville (1996).

[c] Assuming acceptance for processing 26,667 tons of waste material at a price of \$10 and \$15 per tonne for case I and case II, respectively. These input materials undergo a 25% mass reduction over the composting period to produce 20,000 tonnes of compost product.

[d] Assuming 35% effective tax rate.

[e] Assuming 100,000 common shares outstanding and no preferred or dilutive securities.

The cost-volume-profit (CVP) analysis (break-even analysis) is used to determine the effect of changes in the company's selling prices, costs, and volume on its profit in the short term. Reliable CVP analysis requires separating the total costs into variable and fixed costs (Table 8). The company's fixed costs include depreciation, insurance, property taxes, advertising, administrative costs, *etc.*, and are projected to be \$200,000 for the range of output of 15,000-50,000 tonnes of product (Table 8). Direct materials costs, direct labour costs, some selling costs, and part of the overhead are variable costs and are estimated to be \$11.45 tonne^{-1} of the company's product. The difference between unit revenue and unit variable cost, *i.e.* the unit contribution margin equals \$13.55. This is the amount that would contribute to the coverage of the fixed cost and net income after covering the company's variable costs. At the projected cost structure, production and sales of 17,200 tonnes of the product would be a break-even point in units, and \$429,000 in sales revenue would be a break-even point in dollars for the outflow side of the business.

Table 8. Projected annual manufacturing and sales activities of a compost factory

Items	Amount ($)
Variable manufacturing cost (per tonne)	
Direct materials	5.25
Direct labor	2.40
Overhead	0.80
Total	8.45
Variable selling expenses (per tonne)	3.00
Total variable costs	11.45
Fixed costs:	
Manufacturing overhead	150,000
Administrative expenses	50,000
Total fixed costs	200,000
Selling price per ton	25[a]
Units produced and sold (tons)	20,000
Contribution margin income statement for wool waste compost factory at break-even point	
Revenue (17,160 x $25)	429,000
Less: Variable manufacturer	169,000
Variable selling	60,000
Total contribution margin	200,000
Less: Fixed manufacturing costs	150,000
Fixed administrative costs	50,000
Net operating income	0

[a] Weighted average sale price based on assumption that about 10% of product is sold retail in bags.

Increasing sales over 17,200 tonnes at the same cost structure would generate operating income. It is important for the compost factory operator to assure operation at a profitable production volume. Therefore, if the supply of wool by-products is not large enough to generate enough product volume then inclusion of other raw materials (*e.g.*, biosolids, yard waste, cotton gin trash, *etc.*) in production may be necessary.

The tested composts are materials that meet the U.S. EPA's definition of a Class-A product and have physical and chemical properties suitable to support plant growth in a greenhouse when used as components of potting mixes and in the field when applied as a soil amendment. The wool composts can be successfully used as a component of potting mixes to grow ornamentals. Although mixes of various compositions were successful in supporting plant growth, generally, only mixes with higher percentages of composts surpassed the performance of the control treatment.

The wool composts can be successfully used as soil amendments to establish turfgrass. It is expected that these materials can be beneficially used in field vegetable production as well. The greenhouse experiment has shown that wool composts can be used as topsoil to grow sod on plastic. Because of their balanced nutrient composition and favourable chemical and physical properties, the wool composts produced a better grass coverage than the control mix.

At the projected cost structure (fixed costs: \$200,000; variable costs: \$11.45 tonne^{-1}) and at an average sale price of \$25 tonne^{-1}, production and sales of about 17,200 tonnes of the product would be a break-even point in units, and \$429,000 of sale revenue would be a break-even point in dollars for the outflow side of the business. The markets for organic by-products in the state of Georgia in the USA listed in order of decreasing profit margin include retail markets (garden centers), sports turf industries, landscaping industries, greenhouses and nurseries, topsoil blenders, and sod producers. Our analysis indicates that a manufacturing facility that has over 17,200 tonnes of production and sales, would generate a profit and income to the operators.

Acknowledgements

The authors acknowledge the contributions of Ms. Sheila Powell and Mr. Mark Jones in the experimental work. This project was partially funded through the State of Georgia's Consortium for Competitiveness in Apparel, Carpet, and Textile Industries.

References

Composting Council, 1995. *Suggested compost parameters and compost use guidelines*. Composting Council, Alexandria, V A, p. 49.

Das, K.C., E.W. Tollner and P.A. Annis, 1997. Bioconversion process design applied to textile industry solid wastes. Paper No. 97-5022, In: *Proceedings of the annual international meeting of the American Society of Agricultural Engineers*, Minneapolis, Minnesota, August 10-14.

Das, K.C., S. Dudka, E.W. Tollner and P.A. Annis, 2000. Pilot scale composting of yard trimmings, wool fiber waste and biosolids – Dublin-Laurens county pilot project. Unpublished report to Dublin-Laurens county, March 2000 [Available by request to authors].

Das, K.C., J.D. Governo and S.A. Thompson, 2001. Computer tool for composting process site design and cost estimation. *Applied Engineering in Agriculture*, 17(5): 711-718.

Decker, H.F. 1989. Growing sod over plastic. Turf in five weeks. *Landscape Management*, 7: 68-69.

Homgren, C.T., G. Foster, and S.M. Datar, 1999. *Cost Accounting: A Managerial Emphasis*. Prentice Hall, p. 906.

Jarecki, M., C. Chong and R. Voroney, 2005. Evaluation of compost leachates for plant growth in hydroponic culture. *J. Plant Nutrition,* 28(4): 651.

Sparks, D.L. 1996. Methods of Soil Analysis. Part 3, Chemical Methods, SSSA, Madison, WI.

Steuteville, R. 1996. How much does it cost to compost yard trimmings. *BioCycle*, 37(9): 39-40.

Tyler, R.W. 1996. *Winning the organics game: the compost marketer's handbook.* ASHS Press, p. 269.

Walker, P., D. Williams and T.M. Waliczek, 2006. An analysis of the horticulture industry as a potential value-added market for compost. *Compost Science and Utilization*, 14(1): 23-31.

U.S. Census Bureau, 2006. *US Department of Commerce*, 1401 Constitution Blvd. NW, Washington DC 20230.

U.S. Environmental Protection Agency (USEPA), 1993. *Clean Water Act.* Section 503. Vol. 58. No. 32, USEP A, Washington, DC.