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Evaluation of Revegetation from Blanket Applied Composts on a Highway Construction Site

Russell Alan Persyn
South Dakota State University

Tom L. Richard
Pennsylvania State University

Thomas D. Glanville
Iowa State University, tglanvil@iastate.edu

John M. Laflen
Iowa State University

Philip M. Dixon
Iowa State University, pdixon@iastate.edu

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Abstract

Compost has been evaluated as a stormwater best management practice for erosion control, but site revegetation is the ultimate goal of most stormwater plans. In this study, three different composts applied as a surface layer or mulch at two depths of 5 and 10 cm were compared with topsoil and subsoil as a medium for crop growth and weed suppression during revegetation of a highway right-of-way. Compost was shown to be as effective as topsoil and subsoil controls for crop growth, while significantly reducing growth of weed species. There were no significant differences between 5- and 10-cm depths of composts, indicating that the shallower depth would be adequate for establishing a cover crop and achieving weed suppression. Compost mulches offer promising opportunities for crop and weed management during revegetation of roadsides and other disturbed landscapes.

Keywords

Compost, Erosion, Vegetation, Mulch, Construction, Cover crop

Disciplines

Agriculture | Bioresource and Agricultural Engineering | Statistics and Probability

Comments

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EVALUATION OF REVEGETATION FROM BLANKET APPLIED COMPOSTS ON A HIGHWAY CONSTRUCTION SITE

R. A. Persyn, T. L. Richard, T. D. Glanville, J. M. Laflen, P. M. Dixon

ABSTRACT. *Compost has been evaluated as a stormwater best management practice for erosion control, but site revegetation is the ultimate goal of most stormwater plans. In this study, three different composts applied as a surface layer or mulch at two depths of 5 and 10 cm were compared with topsoil and subsoil as a medium for crop growth and weed suppression during revegetation of a highway right-of-way. Compost was shown to be as effective as topsoil and subsoil controls for crop growth, while significantly reducing growth of weed species. There were no significant differences between 5- and 10-cm depths of composts, indicating that the shallower depth would be adequate for establishing a cover crop and achieving weed suppression. Compost mulches offer promising opportunities for crop and weed management during revegetation of roadsides and other disturbed landscapes.*

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Many construction and development activities cause major site disturbances, exposing bare soil to erosion and thereby threatening water quality (USEPA, 2000). Similar disturbances can be caused by natural events, including flooding, landslides, and fires. Revegetation of these sites provides both aesthetic and environmental benefits, but can also pose its own short-term environmental risks before vegetative cover is fully established, including erosion, and herbicide and fertilizer runoff. Alternative strategies that reduce these environmental risks could have widespread application.

Typical revegetation programs depend on large quantities of introduced seed and chemical fertilizer inputs for vegetative establishment, while herbicides are used for weed control. Such systems are generally effective for simple vegetative mixtures, particularly on highly disturbed sites where the pre-existing seed bank in the topsoil has largely been removed or destroyed. However, where seed or planting stock is very expensive (as with many rare and some native species), or where the crop mix is slow growing or intolerant of herbicides, establishment of preferred species can be challenging and slow. Benik et al. (2003a; 2003b) reported that weed species dominated the aboveground biomass harvested on their erosion control plots, and that native grass establishment was not expected in the first 3 years.

These difficult revegetation situations are particularly challenging on steeply sloping sites, where slow cover establishment can leave the soil vulnerable to severe erosion events (Meyer et al., 1971). When rill development becomes excessive, a site must be regraded and reseeded, a cycle that can sometimes be repeated several times.

One alternative strategy for revegetation of disturbed sites is to use compost applied as a surface layer or mulch. The primary purpose of mulches is usually to suppress weed growth, and this function can be accomplished using geotextile fabrics, wood chips, straw, compost, or other materials. Mulches suppress weed growth by creating a physical barrier between weed seeds and the surface, so that plants that germinate under the mulch are unable to grow to the mulch surface before exhausting the seed's energy reservoir. Compost has been attracting renewed interest as a mulch in horticultural applications, where it can serve as one component of an ecological approach to weed management (Altieri and Liebman, 1988). In addition to the physical effect common to all mulch materials, immature composts can suppress weeds (and sensitive crops) by producing phytotoxic compounds (Niggli et al., 1990; Ozores-Hampton et al., 2002a). However, this effect dissipates with increasing compost stability and maturity, as aerobic processes degrade the phytotoxic acids and other implicated biochemical compounds (Tam and Tiquia, 1994). Given these physical and biochemical mechanisms, it is not surprising that both the depth of compost application and compost maturity can significantly affect weed germination and emergence. Ozores-Hampton et al. (2002b) found that immature compost with high concentrations of acetic acid could suppress weed growth at application depths of only 2.5 cm, while 10-cm depths were needed for consistent weed suppression with more mature compost from the same facility.

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The authors are **Russell A. Persyn, ASABE Member Engineer,** Assistant Professor, Department of Agricultural and Biosystems Engineering, South Dakota State University, Brookings, South Dakota; **Tom L. Richard, ASABE Member Engineer,** Associate Professor, Department of Agricultural and Biological Engineering, The Pennsylvania State University, University Park, Pennsylvania; **Thomas D. Glanville, ASABE Member Engineer,** Professor, **John M. Laflen, ASABE Fellow Engineer,** Adjunct Professor, Department of Agricultural and Biosystems Engineering, and **Philip M. Dixon,** Professor, Department of Statistics, Iowa State University, Ames, Iowa. **Corresponding author:** Thomas D. Glanville, Dept. of Agricultural and Biosystems Engineering, Iowa State University, 100 Davidson Hall, Ames, IA 50014; phone: 515-294-0463; fax: 515-294-6633; e-mail: tglanvil@iastate.edu.

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In addition to being effective for weed control (Roe et al., 1993; Maynard, 1998; Ozores-Hampton et al., 2002a), compost can also reduce erosion (Faucette et al., 2004; Persyn et al., 2004), reduce soil temperature fluctuations and evaporation (Pinamonti, 1998), increase soil nutrient levels (He et al., 2002; Sikora and Szmidt, 2002) and thus significantly enhance growth of crop plants (Maynard, 1998; Feldman et al., 2000; Barker, 2002). These benefits can be achieved at a lower cost than for synthetic fabric mulches (Feldman et al., 2000), with application either by bulk handling equipment or blower trucks for flexible and accurate delivery (Alexander, 2002; Block, 2001).

Despite all these benefits, compost is not widely used for revegetation of disturbed landscapes, and demand for compost in many parts of the United States still lags behind supply. One of the larger potential groups of customers for compost is state departments of transportation and other construction companies. These organizations manage the revegetation of thousands of acres each year in many states, often on steep slopes where the risks of erosion are high and rapid crop establishment is critical. This study investigates the use of compost as a growth media for establishing cover crops, and as a mulch for controlling weeds on a disturbed highway right-of-way.

Materials and Methods

Five media consisting of three composts (biosolids compost, yard waste compost, and bio-industrial compost) applied at two depths (5 and 10 cm) and two conventional soil treatments (topsoil applied at 15 cm and compacted subsoil) were applied to a newly constructed highway right-of-way with a 3:1 sideslope and sampled in two different years (table 1). Compost selection was done with the assistance of the Iowa Department of Natural Resources to represent typical composts available in Iowa. Topsoil was included because this is currently used by the Iowa Department of Transportation when the quality of compacted subsoil is inadequate to establish a suitable cover crop for erosion control. Treatments were placed on the foreslopes of a highway overpass near Ames, Iowa, and followed a randomized complete block design. All treatments were replicated six times, with three replications in each year. Parallel studies of the impact of these treatments on soil erosion and associated water quality impacts are reported elsewhere (Glanville et al., 2004; Persyn et al., 2004, 2005).

Physical and chemical characteristics of the composts and soils used in the study were evaluated to characterize the materials. These were previously reported by Persyn et al. (2004) and Glanville et al. (2004), and are summarized in tables 2, 3, and 4.

Table 1. Compost and soil treatment names and descriptions.

Treatment	Material Description and Source	Reps
Biosolids - 5 cm	Sewage sludge and yard waste, 5-cm depth, Davenport Composting Facility	6
Biosolids - 10 cm	Sewage sludge and yard waste, 10-cm depth, Davenport Composting Facility	6
Yard waste - 5cm	Yard waste, 5-cm depth, Des Moines Metro Waste Authority	6
Yard waste - 10 cm	Yard waste, 10-cm depth, Des Moines Metro Waste Authority	6
Bio-industrial - 5 cm	Paper mill sludge and cereal processing mixture, 5-cm depth, Bluestem Solid Waste Agency	6
Bio-industrial - 10 cm	Paper mill sludge and cereal processing mixture, 10-cm depth, Bluestem Solid Waste Agency	6
Subsoil	Existing compacted roadway embankment soil (subsoil)	6
Topsoil	Topsoil, 15-cm depth, from local vicinity of research site	6

Table 2. Physical and chemical characteristics of composts (Persyn et al., 2004).

Year	Media	Moisture Content[a] (%)	C:N Ratio	Bulk Density[b] (kg/m^3)	Size Aggregate (% passing 22.2 mm)	Size Aggregate (% passing 11 mm)	Size Aggregate (% passing 6.35 mm)
1	Biosolids	29	11	514	100	100	96
2	Biosolids	27	11	387	100	97	74
1	Yard Waste	39	13	411	94	88	86
2	Yard Waste	32	13	414	94	85	85
1	Bio-industrial	29	17	557	100	99	94
2	Bio-industrial	28	19	635	100	100	95

[a] Wet basis.
[b] Dry basis.

Table 3. Physical and chemical characteristics of soils (Persyn et al., 2004).

Year	Media	Moisture Content[a] (%)	Carbon (%)	Bulk Density[b] (kg/m^3)	% Sand (0.05-2.00 mm)	% Silt (0.002-0.05 mm)	% Clay (<0.002 mm)
1	Subsoil	5	3.38	1,326	58.1	28.0	13.9
2	Subsoil	6	1.03	1,301	72.5	16.7	10.8
1	Topsoil	10	2.50	1,302	61.5	23.9	14.6
2	Topsoil	6	1.47	1,657	71.8	17.2	11.0

[a] Wet basis.
[b] Dry basis.

Table 4. Nutrient concentrations of composts and soils (Glanville et al., 2004).

Media	Nitrogen (mg/kg^{-1})	Phosphorus (mg/kg^{-1})	Potassium (mg/kg^{-1})
Subsoil	1,070	333	858
Topsoil	1,390	439	746
Biosolids	25,600	15,700	5,950
Yard waste	19,000	2,580	10,900
Bio-industrial	11,800	2,890	3,270

Each plot was constructed by placing compost and topsoil at the desired depth in 1.2- × 1.2-m test plots. All plots were then cultipacked twice, fertilized with 500 kg ha^{-1} of 13-13-13, and seeded, all according to Iowa Department of Transportation specifications (Ole Skaar, Personal Communication, 28 March 2000). The seed mixture included oats, annual ryegrass, red clover, and timothy at rates of 108, 39, 6, and 6 kg ha^{-1}, respectively, and is henceforth referred to as the crop. In the first year, plots were fertilized and planted on 6 June 2000 and in the second year on 5 June 2001. After six weeks of growth, all aboveground vegetation was harvested from a defined sample area, which was placed in the central region of the plot to eliminate any edge effects. In year one the defined sample area was a ring of 0.07-m^2 area and was not large because plots had substantial vegetation growth. Because of the small size of this ring there was some potential for observer bias in the sampling, particularly in the biosolids compost, where year one germination was uneven and bare areas of the plots were intentionally avoided. In year two this potential for bias was much greater because of non-uniform and lack of vegetation; therefore, the sampling area was increased to a 0.50- × 0.75-m rectangle, covering the entire central region of the plot. The sampled biomass was dried at 90°C until it reached a constant weight, and then separated into planted crop species and weed fractions, and was weighed.

Statistical analysis was performed using SAS version 8.0 (SAS, 1999). Analysis of variance (ANOVA) using PROC GLM was used to determine any significant differences between treatments. Contrasts were used to determine significance between compost types, compost depths, and treatment-to-treatment comparisons. Contrasts allow for specific researchable questions to be answered as opposed to other pairwise methods (Keuhl, 2000). Analyses were performed on the log transformation of the data to satisfy the statistical assumptions of normally distributed data and constant variance. Significant differences were determined at the 0.05 level.

Results and Discussion

Adequate soil moisture is critical to any crop's establishment, and differences in precipitation between the two years of this study had a dramatic influence on the results (fig. 1). In year one, rainfall was sufficient to get good crop germination and emergence. In year two there was no rainfall during this critical period (the first few weeks after planting), and while supplemental hand watering was able to help germinate the crop, in most treatments it desiccated and died immediately thereafter. To illustrate the differences experienced under these radically different rainfall regimes, results are presented for the individual years and combined treatments. The mean dry mass of planted crop species, weeds, and total biomass are in figures 2, 3, and 4, respectively.

The lack of rainfall in year 2 eliminated crop growth from all but the topsoil treatment, where residual soil moisture allowed crop growth on one of the three replicates. Weed growth was not as dramatically affected. Interestingly, mean weed biomass values increased for the compost treatments in

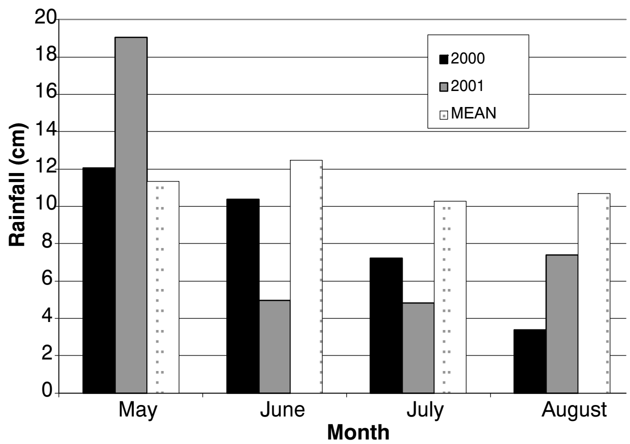

Figure 1. Mean (historical), 2000, and 2001 rainfall data (May through August) for Ames, Iowa (ISU, 2007).

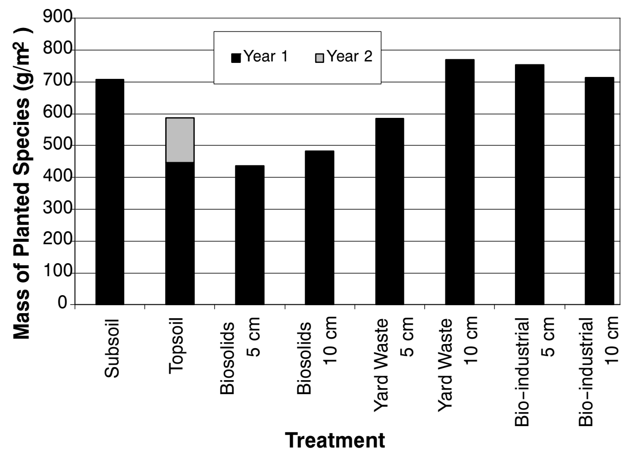

Figure 2. Mass of planted species for compost and soil treatments in Year 1 and Year 2.

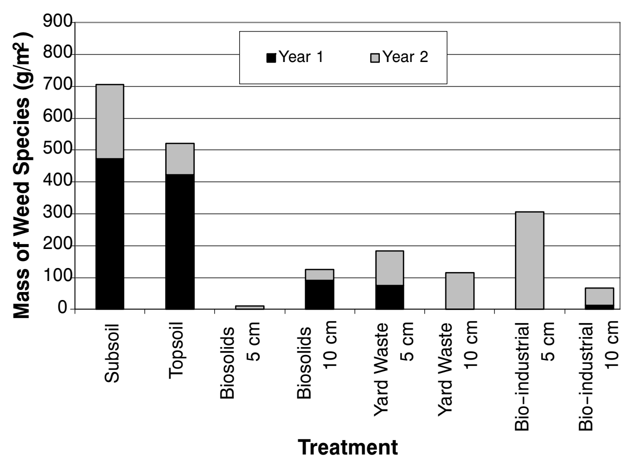

Figure 3. Mass of weed species for compost and soil treatments in Year 1 and Year 2.

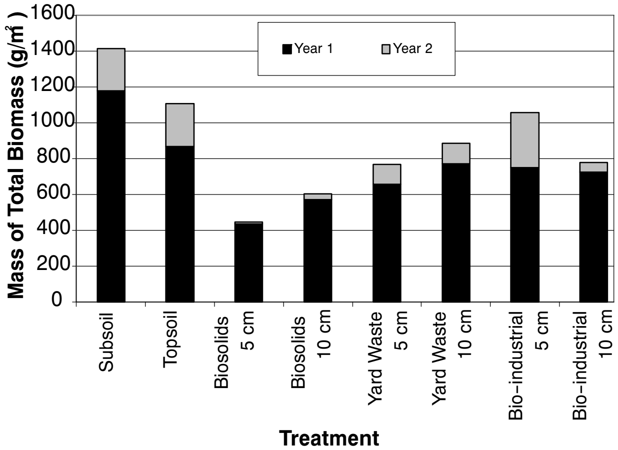

Figure 4. Total biomass (planted species and weed species) for compost and soil treatments in Year 1 and Year 2.

the dry second year in all but the biosolids compost at 10-cm depth (fig. 3). This could be partly an artifact of the smaller sample size in year 1, as no weeds were detected on many of the biosolids samples. The rainfall difference generally resulted in increased standard deviations when data from the two years were combined, with the exception of weed biomass in some treatments.

Results from contrast statements indicated there was no significant effect of compost depth on crop or weed above ground biomass, so depths were combined to examine the effect of media for both years. Combining depths provided 12 replicates of each medium for the compost, and six each for the topsoil and unamended soil control. Mean crop, weed, and total aboveground biomass are presented in tables 5, 6, and 7, respectively. Means with different letter designations are significantly different at the $p < 0.05$ level.

High variability among the replicates resulted in high standard deviations, with the standard deviation often greater than the mean value. There were no significant differences among treatment media with respect to growth of planted species (table 5). However, there were significant effects of treatment media on weed biomass, and also on total biomass. All three composts had significantly lower weed biomass (table 6) relative to both topsoil and the compacted subsoil controls. The greater weed growth in the topsoil and control treatments did provide additional vegetative cover, which would provide some benefits when, as happened in year two, the planted crop fails due to drought. However, this cover was limited and would eventually be removed for reseeding and establishment of the desired crops. Despite differences in total biomass production, Persyn et al. (2004) reported steady-state interrill erosion rates on vegetated plots that were still significantly less on the compost treatments than on the soil treatments.

Total biomass was higher in the subsoil, topsoil, and bio-industrial composts than the biosolids compost (table 7). There were no significant differences in total biomass between the subsoil, topsoil, or bio-industrial compost. The lower growth in the biosolids compost may have been caused by persistence of some phytotoxic compounds in the media the first year, which would explain both the reduced crop emergence (previously mentioned) and the low weed biomass for that treatment. Phytotoxicity, while it can be a serious problem at levels high enough to affect the crop, may, at lower levels, inhibit weed growth of sensitive species without significantly affecting the crop. Strategies that exploit this potential differential effect on weeds are an intriguing area for future research.

Table 5. Mean dry mass of planted species considering media (combined depths, both years).

Media	No.	Mean Mass of Planted Species (g/m^2)[a]	Standard Deviation
Subsoil	6	354a	409
Topsoil	6	294a	258
Biosolids	12	230a	267
Yard waste	12	339a	372
Bio-industrial	12	366a	411

[a] Means with different letter designations are significantly different ($p < 0.05$).

Table 6. Mean dry mass of weed considering media (combined depths, both years).

Media	No.	Mean Weed Mass (g/m^2)[a]	Standard Deviation
Subsoil	6	353b	308
Topsoil	6	260b	287
Biosolids	12	34a	79
Yard waste	12	75a	117
Bio-industrial	12	94a	178

[a] Means with different letter designations are significantly different ($p < 0.05$).

Table 7. Mean dry total above ground biomass considering media (combined depths, both years).

Media	No.	Mean Total Mass (g/m^2)[a]	Standard Deviation
Subsoil	6	707c	646
Topsoil	6	554b,c	373
Biosolids	12	264a	294
Yard waste	12	414a,b	361
Bio-industrial	12	460b,c	360

[a] Means with different letter designations are significantly different ($p < 0.05$).

Conclusions

Three types of compost mulch have been compared with topsoil and subsoil as media for crop growth and weed suppression during revegetation of a highway right-of-way. In this study, the composts were shown to be as effective as topsoil and subsoil for crop growth, while significantly reducing growth of weed species. The topsoil used in this study was a sandy loam soil, and additional crop growth might be achieved with more productive clayey or silty soils. There were no significant differences between 5- and 10-cm depths of compost application, indicating that the shallower depth would be adequate to grow a desired cover crop and maintain weed suppression. The shallower depth was also adequate for erosion control (Persyn et al., 2004) and represents a significant cost savings in the amount of material (vs. 10 cm) needed for erosion control and revegetation. Lack of vegetative growth on construction sites with blanket applied compost might not be as critical or sensitive to dry climate conditions because of the immediate erosion protection provided by the material. Compost mulches offer promising opportunities for crop and weed management during revegetation of roadsides and other disturbed landscapes. There is potential to reduce and eliminate unit operations from a construction site including fertilizer and herbicide application, and the potential to eliminate planting a temporary cover crop as the compost provides the necessary erosion protection, and time for the permanent cover crop to develop.

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