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Evaluation of Soil Erosion and Soil Erodibility Factors for Composted Organics on Highway Right-of-Ways

Russell Alan Persyn
Iowa State University

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

Tom L. Richard
Iowa State University

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Abstract

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Keywords

Compost, Interrill Erosion, Runoff, Erodibility, Construction, Highway Right-of-Ways

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Evaluation of Soil Erosion and Soil Erodibility Factors for Composted Organics on Highway Right-of-Ways

R.A. Persyn

Dept. of Agricultural & Biosystems Engineering, 100 Davidson Hall, Iowa State University, Ames, Iowa 50011 (rap@iastate.edu)

T.D. Glanville

Department of Agricultural & Biosystems Engineering, 201 Davidson Hall, ISU, Ames, Iowa 50011, (tglanvil@iastate.edu)

T.L. Richard

Dept. of Agricultural & Biosystems Engineering, 100 Davidson Hall, Iowa State University, Ames, Iowa 50011 (tlr@iastate.edu)

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Abstract. *Runoff and interrill erosion were measured on three composted organics applied at 5-cm and 10-cm depths, a topsoil treatment (15-cm application), and the existing soil on a highway embankment with a 3 to 1 slope. Treatments were tested immediately after preparation and six weeks later to allow for the vegetative cover crop to grow. Rainfall simulations were conducted at an average intensity of 95 mm/hr. The depth of compost application was a significant factor for runoff rates and infiltration rates of the un-vegetated plots. Compost application depth was not an important factor in measured interrill erosion rates or calculated interrill erodibility factors for un-vegetated plots. The depth of compost application was not a significant factor on the vegetated plots. Vegetated compost treatments were effective at reducing runoff rates and interrill erosion rates compared to the topsoil and control treatments. Compost treatments had significantly lower interrill erosion rates and interrill erodibility factors compared to topsoil and control treatments on un-vegetated plots.*

Keywords. *Compost, Interrill Erosion, Runoff, Erodibility, Construction, Highway Right-of-Ways*

Introduction

The 1987 Amendments to the Clean Water Act (CWA) established the Nonpoint Source Management Program. Furthermore, the 1990 Coastal Zone Act Reauthorization Amendments (CZARA) established the Coastal Nonpoint Pollution Program. These two acts represent significant changes in policy to address nonpoint source pollution (NPS), “the nation’s largest water quality problem” (USEPA, 1996). NPS pollution occurs when a transport medium, such as water, moves pollutants from the land to a water body or into the groundwater supply. According to USEPA (1996), the most common NPS pollutants are sediment and nutrients.

Sediment and nutrients can both become NPS pollution through soil erosion. The impact of soil erosion has historically been viewed as an agricultural problem and the inspiration for major research. However, construction sites have received increased attention concerning soil erosion with the above mentioned amendments to the CWA and CZARA. In fact, highway construction sites have been identified as potential sources of NPS pollution through soil erosion because they can increase the soil loss rates 10 to 20 times those from agricultural lands (EPA, 1997). This concern was addressed directly by Congress in the 1991 Intermodal Transportation Efficiency Act, which prompted the Federal Highway Administration (FHWA) to adopt Erosion and Sediment Control Rules (23 CFR 65) in 1994. This regulation formally adopted the use of Volume III of the 1992 American Association of State Highway and Transportation Officials (AASHTO) Highway Drainage Guidelines. These guidelines are to be applied to all projects, on or off the National Highway System, funded under 23 United States Code (U.S.C.). The upcoming implementation of EPA Phase II rules in 2003 will also extend permitting and pollution prevention plans to construction sites between one and five acres (USEPA, 2002). Currently, the Phase I rules only cover construction sites greater than five acres (USEPA, 2002).

State Departments of Transportation (SDOT) have addressed erosion control on highway construction projects with a number of temporary and permanent control measures. Common practices used by SDOT include silt fences, establishing a temporary or permanent cover crop, synthetic cover mats, and straw. More recently, mulch and compost applications have been targeted as new tools in erosion control. The added benefit of using compost as an erosion control strategy is that it provides another end use for recycled organic wastes. In many states, an increased emphasis has been placed on reducing the volume of materials entering landfills through recycling organic material. This reduction has been accomplished by establishing solid waste composting facilities, which prevent yard and garden wastes, sewage sludge, and other organics from entering the landfill. In addition, the composting process has the ability to reduce the volume of the finished product by up to 50% (NRAES, 1992). In Iowa alone, 323,000 tons of compost is produced each year from the 64 top-producing facilities (DNR, 1998). This represents a 21% increase in compost production since 1996. Compost use in erosion control on highway construction projects has been viewed as a potential beneficial utilization of organic wastes.

Objectives

The objective of this project is to compare the erosion from sites receiving blanket applications of composts, a current practice of applying topsoil, and existing soil conditions on a highway embankment with a 3 to 1 slope. More specifically, this paper will compare runoff rates, infiltration rates, interrill erosion rates, and interrill erodibility factors for compost applications of 5-cm and 10-cm, a topsoil application of 15-cm, and the existing compacted subsoil (control).

Literature Review

Soil erosion is created by erosive agents such as rainfall energy and flowing water, which detach soil particles and transport them to another location (Haan et al., 1994). The process of depositing soil material is called sedimentation. There are two types of erosion processes that detach, transport and deposit soil particles. Interrill erosion is caused by the impact of rain drops on the surface, which cause soil detachment and the subsequent overland flow of soil (Liebenow et. al., 1990). Rill erosion is the result of soil detachment and transport by concentrated flowing waters (Haan et al., 1994). The concentrated flow of water creates a shearing action, which causes small channels (called rills) to develop. Factors that impact rill and interrill erosion include climate, soil, topography and vegetation (DOT, 1995). This paper focuses on the interrill erosion component of this study.

Kinnell and Cummings (1993) developed the following empirical relationship to describe interrill erosion, which is a modification of equation 2 described in Liebenow et al. (1990).

$$D_i = K_i I q S_f \qquad (1)$$ (Kinnell and Cummings, 1993) and

$$D_i = K_i I^2 S_f \qquad (2)$$ (Liebenow et al., 1990)

where, D_i = interrill erosion rate (mean mass of soil eroded/unit area/unit time),

K_i = interrill erodibility,

I = rainfall intensity (depth per unit time),

q = flow discharge (depth per unit time), and

S_f = $1.05 - 0.85\exp(-4\sin\phi)$ where ϕ = the slope angle.

Equation 1 was developed to handle situations where soils have high infiltration rates and was adopted in this study as the preferred method of calculating interrill erodibility factors. Composts, especially when applied as mulch blankets, are expected to have high infiltration rates.

Although scientific quantification of erosion control with compost blankets has been minimal, there are studies that indicated the effectiveness of mulch covers. Duley (1939) published data showing a sandy loam soil covered with straw that had an infiltration rate of 30.5 mm/hr reduced to 6.4 mm/hr after the straw was removed. The infiltration rate increased back to 40.6 mm/hr with the addition of a burlap layer over the soil. Young (1969) suggested that 4.5 tons/ha of grain straw would provide an adequate mulch layer. Lattanzi et al. (1974) reported that straw mulch rates that protect the soil from sealing could greatly reduce the amount of runoff and suggested an application of 8 tons/ha was most successful. A study conducted by Meyer et al. (1971) used a straw mulch treatment of 2.3 tons/ha that effectively controlled soil loss to less than 35 tons/ha compared to a 10-cm topsoil application that lost 77 tons/ha. Their study was on a construction site with a 12 percent slope and 63 mm/hr rainfall intensity was applied.

More recently, several studies and demonstrations have been conducted to evaluate organic waste materials. A survey conducted by Mitchell (1997) reported that 19 SDOT had compost specifications and that six had conducted erosion control experiments. In Connecticut, wood waste materials studied by Demars et al. (2000) were effective at reducing runoff during storms of 12.7 mm/hr or less and effective at controlling erosion with thicknesses of 1.9 cm or more. Their tests were conducted on a highway embankment with a 26 degree slope under natural rainfall conditions.

Compost amended plots and wood mulched plots were compared to synthetic chemical tackifiers by Storey et al. (1996). This study, conducted in Texas, showed that compost and wood mulch applications met the maximum allowable sediment loss standards on a clay and sand soil, but the sediment loss was much less for the compost application on the sand. In fact, compost-treated plots had less than half the erosion of other treatments applied to the sandy soil.

Stewart and Pacific (1993) suggested blanket applications of 7.5 cm and Michaud (1995) suggested blanket applications of 10 cm. Michaud (1995) further explained that 10-cm applications would effectively control erosion on slopes up to 45 percent for 1 to 3 years.

A two-year study completed in 1998 by the Connecticut Departments of Environmental Protection and Transportation evaluated erosion on experimental plots constructed on a new roadway embankment with 2:1 slopes. Eight plots were treated with 3.8– or 7.6–cm depths of composted yard waste, wood mulch, and straw. Erosion on the untreated control plot was reported to be more than 10 times that produced on any of the mulched plots. Thickness of the mulch layer did not appear to significantly affect the observed erosion rates (Block, 2000).

Agassi et al. (1998) studied the effects on storm runoff of surface-applied municipal solid waste compost. One- to three-centimeter thick layers of compost were surface applied to identically prepared loess soils placed in small boxes and subjected to six simulated rainfalls totaling 260 mm. Approximately 85% of applied rainfall infiltrated into compost-treated plots while 52% or less was absorbed by control plots.

Risse et al. (2002) conducted a study on various compost and soil treatments on a 10 percent slope receiving an average rainfall intensity of 16.7 cm/hr. Their findings were a reduction in total solids in the runoff for all composts and wood mulches compared to a bare soil treatment, and the total eroded solids were significantly less for the biosolids, yard waste, food waste composts, and wood mulch products. Runoff rates were lower in most cases, but not significantly lower.

Materials and Methods

Five media consisting of a biosolids compost, yard waste compost, bio-industrial compost, topsoil, and control soil were tested in two different years on vegetated and un-vegetated plots (table 1). Compost selection was done with the assistance of the Iowa Department of Natural Resources to represent typical composts available in Iowa. Treatments were placed on the foreslopes of a highway overpass near Ames, Iowa, and followed a randomized complete block design. All treatments were replicated 6 times on vegetated and un-vegetated plots (3 replications per year).

Table 1. Treatment names and descriptions

Treatment	Description	Reps/ Veg.
A5	Biosolids Compost 5 cm Depth--Davenport Composting Facility	6
A10	Biosolids Compost 10 cm Depth--Davenport Composting Facility	6
B5	Yard Waste Compost 5 cm Depth--Des Moines Metro Waste Authority	6
B10	Yard Waste Compost 10 cm Depth--Des Moines Metro Waste Authority	6
C5	Bio-industrial Compost 5 cm Depth--Bluestem Solid Waste Agency	6
C10	Bio-industrial Compost 10 cm Depth--Bluestem Solid Waste Agency	6
P0	Compacted Subsoil (Control)	12
T15	Topsoil 15 cm Depth	12

Physical and chemical characteristics of the composts and soils used in the study are summarized in tables 2 and 3. Bulk density and moisture content was measured as described in Milford (1991) and in the Test Methods for the Examination of Composting and Compost (TMECC) (USCC, 1997). The Iowa State University (ISU) Agronomy Textural Laboratory conducted textural class identification. The C:N ratio was calculated by analysis of carbon and nitrogen on a CHN-2000 Analyzer and the textural classes in the ISU Agronomy Soils Testing Laboratory. The aggregate size analysis was also conducted following procedures outlined in the TMECC. Additional chemical analysis of the composts and soils is available in Glanville et al. (2002).

Table 2. Physical and chemical characteristics of composts.

Year	Media	Moisture Content (%)	C:N Ratio	Bulk Density (kg/m^3)	Size Aggregate (%>22.2 mm)	Size Aggregate (%>11 mm)	Size Aggregate (%>6.35 mm)
1	A	29	11	514	100	100	96
2	A	27	11	387	100	97	74
1	B	39	13	411	94	88	86
2	B	32	13	414	94	84	85
1	C	29	17	557	100	99	94
2	C	28	19	635	100	100	95

Table 3. Physical and chemical characteristics of soils.

Year	Media	Moisture Content (%)	C:N Ratio	Bulk Density (kg/m^3)	% Sand	% Silt	% Clay
1	P	5	23	1,326	58.1	28.0	13.9
2	P	6	15	1,301	72.5	16.7	10.8
1	T	10	15	1,302	61.5	23.9	14.6
2	T	6	13	3,038	71.8	17.2	11.0

Each plot was constructed by placing compost and topsoil down at its desired depth in 1.2-m by 1.5-m plots in year one and 1.2-m by 1.2-m plots in year two. The size varied between years because the available area in year 2 was less. All plots were cultipacked twice and vegetated plots were fertilized and seeded according to Iowa Department of Transportation specifications. Plots were raked level and galvanized frames 0.50-m by 0.75-m were hand driven into the middle of the plot to eliminate any edge effects. Galvanized collectors were installed prior to rainfall simulation at the downhill side of the plot.

Data collection procedures for interrill erosion were adopted from those described in Liebenow et al. (1990) and performed on bare plots immediately after construction and on vegetated plots 6 weeks after cover crop development. A Norton rainfall simulator developed by the National Soil Erosion Research Laboratory was used for all simulations in this study. Each rainfall simulation setup allowed for the collection of runoff from five treatments. Treatments were randomly assigned within a simulation setup, but grouped by the depth of compost application and always contained a topsoil and control treatment. Rainfall was measured at the top of each plot and used in all subsequent analysis and calculations. Once runoff began on an individual treatment, a sample was collected at five-minute intervals for a total of one hour. Data showed that steady state flow conditions were achieved during the last 20 minutes of sampling and runoff rates and interrill erosion rates were determined by averaging the last four values, unless one value differed largely from the other values. Infiltration rates were determined by subtracting the runoff rate from the rainfall intensity.

Runoff rates were determined from the weight of runoff divided by the sample collection time. Runoff rates were converted into a depth per unit time by assuming a density of 1000 kg/m^3 and the plot area of 0.375-m^2. Total solids analysis was conducted on each runoff sample by extracting thoroughly mixed triplicate samples, centrifuging the sample to settle all solids, extracting a portion of the supernatant for dissolved solids analysis, and drying samples at 104 ^{o}C. The samples were corrected for the portion of dissolved solids that remained in the tube, yielding total suspended solids. This value of total suspended solids was used in all calculations of interrill detachment rates.

Statistical analysis was performed using SAS version 8.0 (SAS, 1999). Analysis of variance (ANOVA) using PROC GLM was used to determine significant differences of treatments. In all cases except the infiltration rate data, contrast statements were used to determine significance between compost types, compost depths, and treatment to treatment comparisons. The infiltration rates on the un-vegetated treatments were analyzed using a Tukey's pairwise comparison because of significance in the depth of compost application. Significant differences were determined at the 0.05 level.

Results and Discussion

Rainfall Intensity

Rainfall intensities were first applied at a target rate of 63 mm/hr and then subsequently increased in year 1 to a target rate of 100 mm/hr. The increase was necessary to produce runoff on compost plots within a reasonable sampling time of about 1 hour. By the last sampling of the un-vegetated interrill plots in year 1, the target rate was set at 100 mm/hr and maintained at this level throughout the study. Rainfall intensities were not statistically significant among the eight treatments, and the overall mean intensity applied during the two-year study was 95 mm/hr (table 4). The ramping of the intensity in year 1 on the un-vegetated plots did not impact the significance because the experimental design allowed for the ramping to equally affect all treatments.

Table 4. Mean rainfall intensity for 6 compost treatments, control, and topsoil separated by vegetation.

Treatment	No.	Un-Vegetated		Vegetated	
		Mean Rainfall Intensity (mm/hr)	Standard Deviation	Mean Rainfall Intensity (mm/hr)	Standard Deviation
A5	6	84.81^{a}	17.15	108.19^{a}	14.01
A10	6	102.38^{a}	18.67	93.02^{a}	21.62
B5	6	98.58^{a}	17.68	92.23^{a}	17.65
B10	6	86.48^{a}	16.49	105.39^{a}	21.00
C5	6	80.39^{a}	18.62	95.72^{a}	12.12
C10	6	100.37^{a}	22.96	97.58^{a}	18.00
P0	12	92.09^{a}	19.65	94.87^{a}	19.19
T15	12	87.80^{a}	29.48	106.23^{a}	14.18

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

Runoff Rate

Runoff rates varied between treatments but there was no significance between un-vegetated an vegetated treatments (table 5). The ANOVA resulted in significant differences among treatments for both the un-vegetated ($p<0.0001$) and vegetated treatments ($p<0.0001$). There were no significant differences between year 1 and year 2 data as well as no significant differences between the interaction of year and vegetation.

Contrast statements were used to determine differences between compost treatments, the interaction between compost and depth, and application depths. Results showed significant differences between compost treatments for the un-vegetated data ($p=0.0006$), but no significant differences in runoff rate for the vegetated data ($p=0.1083$). The interaction between compost and depth was not significantly different for both vegetative conditions, but the 5-cm depths were statistically higher for the un-vegetated data and not significant for the vegetated data.

Since compost depth equally affected runoff from each compost media, mean runoff rates from 5-cm and 10-cm depths were pooled for each media. Pooled data were further analyzed with contrast statements to determine significance between treatments. For all compost media, the runoff rates were lower compared to the control and topsoil, but were all statistically lower than the control on the un-vegetated plots and statistically lower than both the control and topsoil on the vegetated plots. Overall, the yard waste compost (B) had the lowest runoff rate and was statistically lower than all other media on the un-vegetated plots and statistically lower than all media except the bio-industrial compost on the vegetated plots.

Table 5. Mean runoff rate for 6 compost treatments, control, and topsoil separated by vegetation.

Treatment	No.	Un-Vegetated		Vegetated	
		Mean Runoff Rate (mm/hr)	Standard Deviation	Mean Runoff Rate (mm/hr)	Standard Deviation
A5	6	41.55	21.88	20.53	24.46
A10	6	37.24	24.55	19.50	16.63
A	12	39.40[a,d]	22.28	20.02[a]	19.95
B5	6	15.93	9.32	5.53	6.52
B10	6	11.95	7.62	1.25	1.31
B	12	13.94[b]	8.37	3.39[b]	5.01
C5	6	38.97	23.46	24.53	32.91
C10	6	15.81	8.51	5.54	5.19
C	12	27.39[a]	20.72	15.03[a,b]	24.55
P0	12	65.44[c]	23.33	55.10[c]	28.77
T15	12	47.58[d]	12.89	56.35[c]	21.00

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

Infiltration Rate

Infiltration rates are not a direct input into the calculation of interrill erodibility, but it was a factor used to determine the decision to adopt equation (1) in determining soil erodibility factors. The infiltration rate was calculated by subtracting the runoff rate from each plot from the rainfall rate. Mean infiltration rates are summarized in table 6 and shows that there were significant differences between vegetated and un-vegetated treatments and that the vegetated treatments have a statistically higher infiltration rate than the un-vegetated treatments ($p=0.0061$). Results of the contrast statements showed that there were significant differences among compost types, between the depths among compost types, and between 5-cm and 10-cm treatments for the un-vegetated data. Therefore, data was not pooled for 5-cm and 10-cm depths on the subsequent analysis, which was conducted using a Tukey's pairwise comparison. Infiltration rates on the un-vegetated compost treatments were higher than the topsoil and control, and were statistically higher on the yard waste 5-cm (B5), yard waste 10-cm (B10), and bio-industrial 10-cm treatments (C10).

Vegetated plots had significantly similar infiltration rates among compost types, between the depths among the compost types, and between 5-cm and 10-cm treatments. Therefore, data was pooled and contrasts showed that all three compost media had significantly higher infiltration rates compared to the topsoil and control, which were statistically similar.

Table 6. Mean infiltration rate for 6 compost treatments, control, and topsoil separated by vegetation.

Treatment	No.	Un-Vegetated		Vegetated	
		Mean Infiltration Rate (mm/hr)	Standard Deviation	Mean Infiltration Rate (mm/hr)	Standard Deviation
A5	6	$43.26^{a,c}$	28.98	87.66	22.88
A10	6	$65.14^{a,b,d}$	18.60	73.52	26.01
A	12	54.20	25.87	80.59^{a}	24.49
B5	6	82.65^{b}	14.28	86.70	20.01
B10	6	$74.52^{a,b}$	14.78	104.14	20.61
B	12	78.58	14.49	95.42^{a}	21.40
C5	6	$41.42^{a,c}$	18.58	71.19	22.91
C10	6	84.56^{b}	25.39	92.05	18.73
C	12	62.99	30.95	81.62^{a}	22.73
P0	12	28.17^{c}	19.38	41.31^{b}	31.25
T15	12	$40.23^{c,d}$	22.60	49.88^{b}	25.24

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

Interrill Erosion

Interrill erosion rates, summarized in table 7, were compared using the same statistical procedures as outlined in previous sections, but on the log transformation of the data. The log transformation was shown to be necessary to satisfy the statistical assumptions that the data were from a normal distribution with constant variance. The determination was made by evaluating residual plots of the data and performing a Box-Cox procedure to indicate the most appropriate transformation. The un-vegetated data had a significantly higher interrill erosion rate compared to the vegetated data ($p=0.0017$). For both un-vegetated and vegetated data, the compost types were significantly different, but the depth was not significant. Therefore, both data sets from the 5-cm and 10-cm depths were pooled for the compost treatments. Compost treatments had significantly less interrill erosion rates compared to the topsoil and control under both vegetated conditions. Among the compost types, the yard waste compost was significantly less than the biosolids and bio-industrial composts, which were statistically similar.

Table 7. Mean interrill erosion rate for 6 compost treatments, control, and topsoil separated by vegetation.

Treatment	No.	Un-Vegetated		Vegetated	
		Mean Interrill Erosion Rate (mg/m^2-sec)	Standard Deviation	Mean Interrill Erosion Rate (mg/m^2-sec)	Standard Deviation
A5	6	28.82	28.84	3.40	3.70
A10	6	27.39	28.81	8.57	14.30
A		28.10[a]	27.49	5.98[a]	10.32
B5	6	4.49	5.40	0.12	0.09
B10	6	4.86	5.63	0.08	0.08
B		4.68[b]	5.27	0.10[b]	0.09
C5	6	18.87	20.86	3.69	5.19
C10	6	9.89	7.85	4.36	10.24
C		14.38[a]	15.74	4.03[a]	7.75
P0	12	116.06[c]	97.98	20.01[c]	17.12
T15	12	166.89[c]	116.81	83.63[c]	104.62

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

Slope Factor

The slope factor is a direct input to the calculation of interrill erodibility. Although a uniform slope would have been ideal, the slope did vary across the project site (table 8). The use of blocking and randomly assigning treatments across the slope was employed as a method to remove any bias; however, there were differences among the treatments. On the un-vegetated plots the yard waste treatment slope factor was statistically higher than the topsoil and control, but on the un-vegetated plots the yard waste slope factor was only statistically higher than the topsoil. A steeper slope would be expected to produce more interrill erosion, but the yard waste always had significantly lower interrill erosion rates. Any differences caused by the slope should be normalized through the calculation of the interrill erodibility factor, which produced similar results to the interrill erosion rates. Therefore, any differences in slope did not significantly change the comparison among treatments.

Table 8. Mean slope factor for 3 compost media, control, and topsoil separated by vegetation.

Treatment	No.	Un-Vegetated Mean Slope Factor	Un-Vegetated Standard Deviation	Vegetated Mean Slope Factor	Vegetated Standard Deviation
A	12	$0.72^{a,b}$	0.05	$0.72^{a,b}$	0.07
B	12	0.75^{b}	0.04	0.76^{b}	0.09
C	12	0.68^{a}	0.08	$0.73^{a,b}$	0.07
P0	12	0.67^{a}	0.13	$0.72^{a,b}$	0.14
T15	12	0.69^{a}	0.09	0.67^{a}	0.13

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

Interrill Erodibility

Interrill erodibility was calculated for each plot based on equation (1) developed by Kinnell and Cummings (1993). Mean interrill erodibility factors are presented in table 9. Statistics were calculated on the log transformation of the data to satisfy the assumption of normal data with constant variance. There were no significant differences between compost depths; therefore, data was pooled by compost type. Compost treatments had significantly lower interrill erodibility factors than either the topsoil or control for the un-vegetated plots. On the vegetated plots, all composts had interrill erodibility factors that were lower than the topsoil or control, but were statistically lower compared to the topsoil. Only the interrill erodibility factors of the yard waste and bio-industrial waste composts were statistically lower than the control. The lower erodibility factors were expected since compost treatments had lower runoff rates and interrill erosion rates compared to the topsoil and control.

Table 9. Mean interrill erodibility factor for 6 compost treatments, control, and topsoil separated by vegetation.

Treatment	No.	Un-Vegetated Mean Interrill Erodibility Factor x 10^{-6} (kg-sec/m^4)	Un-Vegetated Standard Deviation	Vegetated Mean Interrill Erodibility Factor x 10^{-6} (kg-sec/m^4)	Vegetated Standard Deviation
A5	6	0.15	0.16	0.03	0.02
A10	6	0.10	0.07	0.06	0.05
A	12	0.12^{a}	0.12	$0.05^{a,c}$	0.04
B5	6	0.04	0.04	0.01	0.01
B10	6	0.06	0.05	0.01	0.01
B	12	0.05^{b}	0.04	0.01^{b}	0.01
C5	6	0.12	0.07	0.02	0.03
C10	6	0.10	0.06	0.07	0.15
C	12	0.11^{a}	0.06	$0.05^{a,b}$	0.11
P0	12	0.67^{c}	0.13	0.06^{c}	0.03
T15	12	0.72^{d}	0.39	0.32^{d}	0.38

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

Time to Initiate Runoff

All evaluations of interrill erosion and runoff were based on data collection once erosion was initiated. Rainfall intensity was increased in the first year to initiate runoff within a reasonable sampling period; however, all treatments responded differently as shown in table 10. Sampling on the topsoil and control treatments occurred within a few minutes of rainfall simulation while the compost treatments required a longer duration, averaging 30 minutes or longer. Overall, the compost treatments had significantly longer times than either the topsoil and control treatments on both the vegetated and un-vegetated plots. The length of time required to initiate runoff shows further indication that the three composts not only have lower runoff rates and interrill erosion rates, but they remain lower even after a longer duration of applied rainfall.

Table 10. Mean time to initiate runoff for 6 compost treatments, control, and topsoil separated by vegetation.

Treatment	No.	Un-Vegetated		Vegetated	
		Mean Time (min)	Standard Deviation	Mean Time (min)	Standard Deviation
A5	6	19.17	9.22	18.83	10.67
A10	6	43.00	54.09	39.83	42.82
A	12	31.08[a]	39.03	29.33[a]	31.71
B5	6	61.17	48.55	33.17	27.31
B10	6	52.67	51.64	92.67	44.18
B	12	56.92[b]	47.99	62.92[b]	46.81
C5	6	27.67	10.91	26.33	30.54
C10	6	36.67	29.08	66.83	46.67
C	12	32.17[a,b]	21.46	46.58[a,b]	43.14
P0	12	4.67[c]	2.02	5.58[c]	4.91
T15	12	7.83[d]	3.79	4.25[c]	2.86

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

Conclusions

All compost treatments were effective at reducing runoff rates and interrill erosion rates under the conditions simulated in this study. Interrill erodibility factors were calculated for all treatments based on equation 1, which will be important for future modeling of these materials under different site conditions. Major findings of this research can be summarized as follows:

- Vegetation was an important factor in reducing interrill erosion rates, lowering the soil erodibility factor, and increasing infiltration.
- The depth of compost application was a significant factor for runoff rates and infiltration rates of the un-vegetated plots. The 10 cm compost application significantly lowered runoff rates and increased infiltration rates compared to the 5 cm compost treatments.

- Compost application depth was not an important factor in measured interrill erosion rates or calculated interrill erodibility factors for un-vegetated plots.
- The depth of compost application was not a significant factor on the vegetated plots.
- Vegetated compost treatments were effective at reducing runoff rates and interrill erosion rates compared to the topsoil and control treatments.
- Compost treatments had significantly lower interrill erosion rates and interrill erodibility factors compared to topsoil and control treatments on un-vegetated plots. This proves that compost can effectively reduce interrill erosion from the time of installation.
- Compost treatments required significantly longer times to initiate runoff than soil treatments.

These findings provide good evidence that compost application on highway right-of-ways can effectively reduce interrill erosion from the time of installation under these simulated conditions. In many cases, compost performance between vegetated treatments in year 1 and year 2 were similar despite a reduction in vegetative growth as reported in Richard et al. (2002). However, these results do further support the benefit of establishing vegetation as a form of erosion control. Lastly, the increased time to initiate runoff at an average rainfall intensity of 95 mm/hr, an intensity greater than a 100-year design storm for central Iowa, further supports the effectiveness of these three composts compared to the two soil treatments (IDOT, 2000).

Future work needs to focus on determining if erodibility factors can be incorporated into erosion models such as the Water Erosion Prediction Project to aid in erosion prediction at different site conditions. In addition, the rill erosion component also needs to be incorporated to obtain both erosion processes in model implementation.

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