Stormwater Runoff & Erosion

How They Occur
&
How Composted Organics Can Control Them

presented by

Dr. Tom Glanville

Department of Agricultural & Biosystems Engineering

IOWA STATE UNIVERSITY

Soil Erosion

- The largest contributor to pollution of U.S. streams, lakes, estuaries
- Impacts
  - Aesthetic - cloudy water, reduces recreational value
  - Ecological – impairs habitat, reduces diversity of stream biota
  - Chemical – carries valuable nutrients, pesticides, other harmful chemicals from point of use into receiving waters
  - Economic - increases water filtration costs, requires costly repairs of eroded land, and clogged waterways

- Construction site erosion …. causes
  - soil loss rates 10 -20X those in agriculture

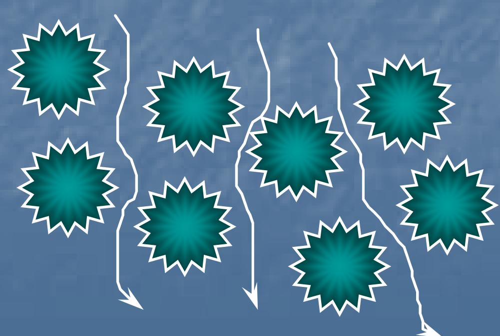
- Preventing erosion …… more effective than trying to control it after it gets started !!

- To prevent erosion, must understand how it occurs

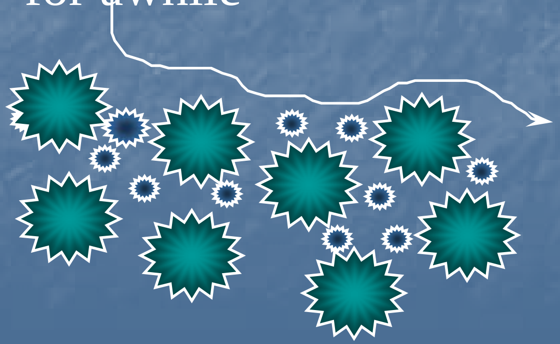
How Runoff and Erosion Occur

- Raindrop impact on bare soil
  - breaks down soil particles
  - makes them easier to move.
- Soil sealing
  - small soil particles move into pore spaces
  - plugs soil surface
  - decreases infiltration …… increases runoff

Before rainfall



After rainfall has occurred for awhile



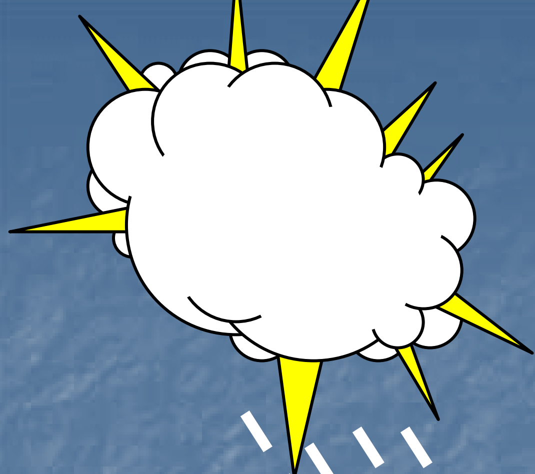
Steps in Soil Erosion

- Small soil particles carried away by thin sheet of water.... "sheet erosion" (aka "interrill erosion")
- Uneven removal of soil during sheet erosion creates tiny crevices (rills) in soil

Steps in Soil Erosion

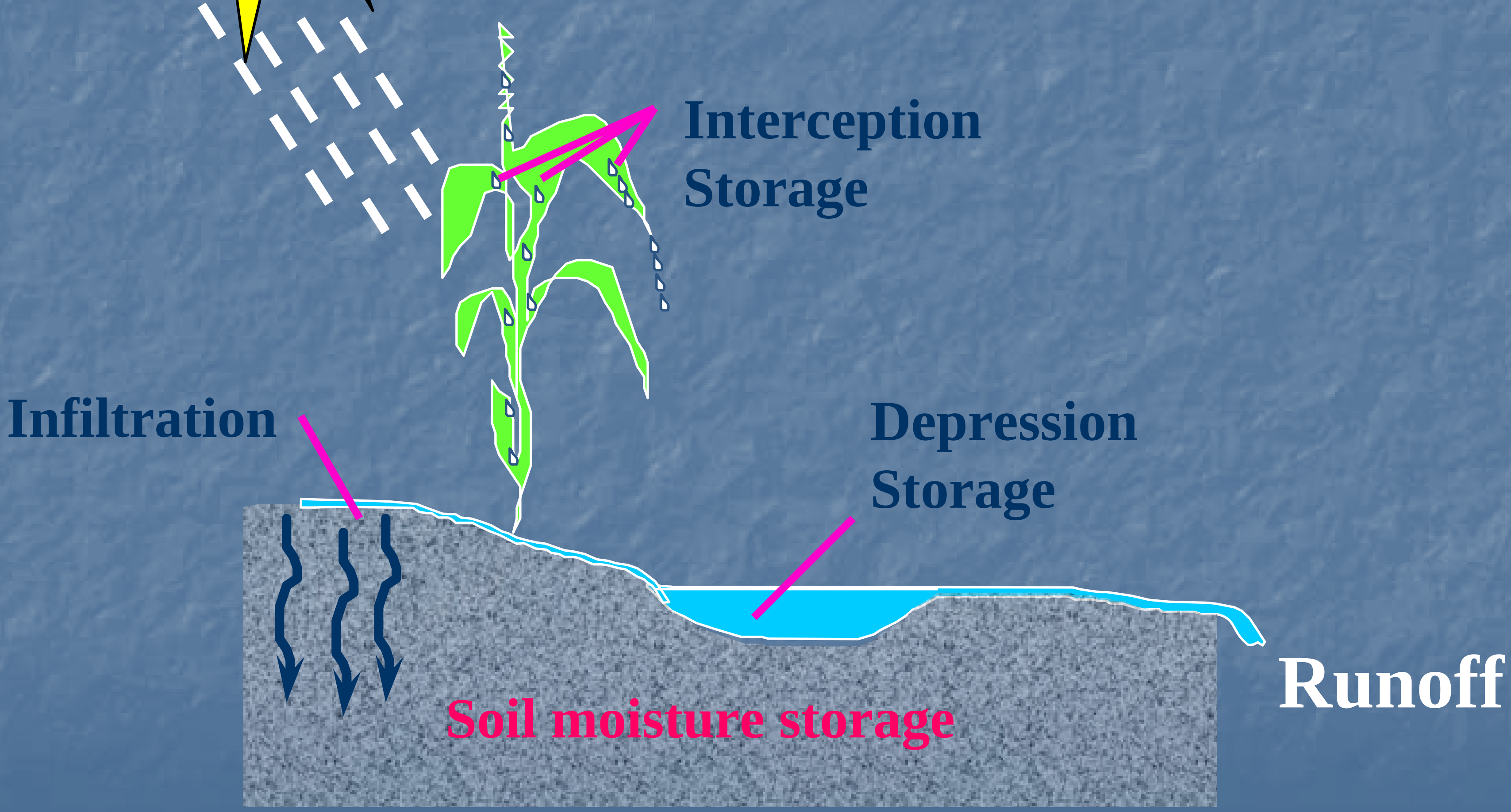
- Runoff concentrates in rills ..... flow velocity increases ... leading to rapid soil cutting and loss (rill erosion) and gullying

- Chemical pollutants ... carried with eroded soil ...... enter storm sewers, drainage ways, streams, lakes



Factors that reduce runoff

- Interception of rainfall on vegetation
- Storage of runoff in depressions
- Rate of infiltration into soil
- Water holding capacity of topsoil



Ways to Reduce Runoff – Prevent Soil Erosion

- Reduce raindrop impact on bare soil
  - Apply mulch over bare soil …. reduce raindrop impact …. prevent production of small easily- moved soil particles
  - Use a topsoil that grows vegetation quickly
- Reduce storm water runoff
  - Increase vegetation …increases interception … reduces soil moisture
  - Use durable coarse textured topsoil …. maintain infiltration rate
  - Use topsoil that absorbs and retains internal water
  - Use a rough textured topsoil … stores water in depressions on its surface
- Field research sponsored by Iowa DOT, Iowa DNR, and others shows compost can do ALL of the above

Iowa DNR / Iowa DOT Test Plots

Located on re-graded I-35 overpass

Compost Treated Areas – <u>blanket</u> application of 3 types of compost

Untreated (control) Areas - compacted subsoil OR subsoil + 6" topsoil

Research Questions Addressed

- Do highway embankments blanketed with compost perform as well as those treated conventionally?
- Do certain types of composts perform significantly better than others?
  - 3 types tested….yard waste, biosolids, bio-industrial
- Does the depth of compost application significantly affect performance?
  - 2 depths tested .... 5 cm & 10 cm
- Does vegetation significantly affect performance?
  - plots tested with ... and without vegetation
- Are compost blankets equally effective for all types of erosion?
  - interrill erosion (caused by raindrop impact & sheet flow)
  - rill erosion (caused by concentrated flow)
- How do compost blankets affect vegetation ?
  - cover crop emergence and growth
  - weed emergence and growth

Erosion & Runoff Testing Using USDA Rainfall Simulator

Insures consistent rainfall intensity and duration during erosion testing

Interrill Erosion Test

Composts

Bio-Industrial

Biosolids

Yardwaste

Compacted Subsoil

Topsoil

Rill Erosion Tests

Surface Texture

Composts much <u>coarser</u> than most soils

topsoil

yard waste

bio-industrial

bio-solids

Research Results

Time to Initiate Runoff

Treatment	No.	Un-Vegetated: Mean Time (min)	Vegetated: Mean Time (min)
Biosolids (A)	12	31.08^{b}	29.33^{b}
Yard Waste (B)	12	56.92^{a}	62.92^{a}
Bio-industrial (C)	12	32.17^{a,b}	46.58^{a,b}
Control (P)	12	4.67^{c}	5.58^{c}
Topsoil (T)	12	7.83^{d}	4.25^{c}

Means within the same column with different letter designations are significantly different ($p<0.05$).

Most Desirable | Medium | Least Desirable

Conclusion: Areas treated with compost took 4 -10 X <u>longer</u> than soils to produce runoff following initiation of intense rainfall.

Research Results

Total Runoff Volume

Un-vegetated plots -- 30-minute storm

	N	Biosolids	Yard Waste	Bio-industrial	Control	Topsoil
		Geo. Mean	Geo. Mean	Geo. Mean	Geo. Mean	Geo. Mean
Runoff (mm)	12	0.13[b]	<0.01[a]	0.08[a,b]	26.22[c]	15.54[c]

Most Desirable | Medium | Least Desirable

Conclusion: Runoff volume from compost treated areas less than 1% of runoff from soils.

Research Results

Total Mass of Interrill Erosion

Un-vegetated plots -- 30-minute storm

	N	Biosolids	Yard Waste	Bio-industrial	Control	Topsoil
		Geo. Mean	Geo. Mean	Geo. Mean	Geo. Mean	Geo. Mean
Eroded Solids (mg)	12	7.84[b]	0.02[a]	2.52[b]	42,714[c]	40,046[c]

Most Desirable | Medium | Least Desirable

Conclusion: Mass of interrill erosion from compost treated areas less than 0.02% of that from soils.

Research Results
Rill Erosion
Concentration of eroded solids

Treatment	Un-Vegetated N	Un-Vegetated Rill Solids Conc. (g/g)	Vegetated N	Vegetated Rill Solids Conc. (g/g)
Biosolids (A)	12	0.058[b]	12	0.019[b]
Yard Waste (B)	12	0.014[a]	12	0.006[a]
Bio-industrial (C)	12	0.060[b]	12	0.018[b]
Control (P)	6	0.038[a,b]	6	0.004[a]
Topsoil (T)	6	0.221[c]	6	0.041[c]

Means within the same row with different letter designations are significantly different ($p<0.05$).

Most Desirable | Medium | Least Desirable

Conclusion: Concentrations of eroded solids in runoff from rilled areas treated with compost…… well below those from imported topsoil but NOT greatly different from native subsoil.

Research Results

Chemical Concentrations in Composts & Soils

Element	N	Biosolids (A)	Yard Waste (B)	Bio-industrial (C)	Control (P)	Topsoil (T)
		Mean (mg/kg)	Mean (mg/kg)	Mean (mg/kg)	Mean (mg/kg)	Mean (mg/kg)
As	6	<1.20[a]	4.62c	1.97[b]	4.82[c]	3.82[c]
Cd	6	1.63[b]	<1.20a	<1.20[a]	<1.20[a]	<1.20[a]
Cr	6	61.69[d]	9.12[b]	15.99[c]	9.78[a,b]	8.25[a]
Cu	6	193.57[d]	21.33[b]	69.46[c]	6.95[a]	8.73[a]
Hg	6	2.37[b]	1.61[a,b]	<1.20[a]	<1.20[a]	<1.20[a]
Mo	6	7.49[b]	0.88a	1.63[a]	<1.20[a]	<1.20[a]
Ni	6	18.74[c]	9.90a	14.68[b]	11.93[a,b]	8.64[a]
Pb	6	70.44[d]	26.09[b]	59.12[c]	19.66[a,b]	13.72[a]
Se	6	<1.20[a]	<1.20[a]	<1.20[a]	<1.20[a]	<1.20[a]
Zn	6	1,033.5[d]	139.36[b]	307.63[c]	42.67[a]	45.72[a]
N	6	25,560[d]	18,962[c]	11,758[b]	1,070.1[a]	1,391.3[a]
P	6	15,702[d]	2,582.3[b]	2,887.6[c]	332.53[a]	438.96[a]
K	6	5,951.8[c]	10,906[d]	3,269.1[b]	858.03[a]	746.39[a]

Means within the same row with different letter designations are significantly different (p<0.05).

Most Desirable | Medium | Least Desirable

Conclusion: Many composts (particularly biosolids) typically have greater metal and nutrient concentrations than soils.

Research Results

Soluble Mass of Chemicals in Runoff

Un-vegetated Plots -- 30-minute storm @ 4 inches/hr

Parameter	N	Biosolids Geo. Mean[1] (mg)	Yard Waste Geo. Mean (mg)	Bio-industrial Geo. Mean (mg)	Control Geo. Mean (mg)	Topsoil Geo. Mean (mg)
Zn	12	<0.01[a]	<0.01[a]	<0.01[a]	0.15[b]	0.16[b]
P	12	0.17[b,c]	<0.01[a]	0.01[a,b]	1.38[c]	0.76[c]
K	12	1.08[a]	0.09[a]	0.29[a]	49.55[b]	18.01[b]

Means within the same row with different letter designations are significantly different ($p<0.05$).
[1]Geometric (Geo.) Mean

Most Desirable | Medium | Least Desirable

Conclusion: The <u>total soluble mass</u> of nutrients and metals in runoff from composted areas less than 7 % of that in runoff from soils

Research Results

Adsorbed Mass of Chemicals in Runoff

Un-vegetated Plots -- 30-minute storm @ 4 inches/hr

Parameter	N	Biosolids Geo. Mean[1] (mg)	Yard Waste Geo. Mean (mg)	Bio-industrial Geo. Mean (mg)	Control Geo. Mean (mg)	Topsoil Geo. Mean (mg)
Cr	12	0.01[b]	<0.01[a]	<0.01[b]	0.92[c]	0.76[c]
Cu	12	0.02[b]	<0.01[a]	0.01[b]	1.03[c]	0.66[c]
Ni	12	<0.01[b]	<0.01[a]	<0.01[b]	0.96[c]	0.67[c]
Pb	12	0.01[b]	<0.01[a]	<0.01[b]	1.82[c]	0.95[c]
Zn	12	0.10[b]	<0.01[a]	0.03[b]	6.55[c]	3.99[c]
N	12	0.47[b]	<0.01[a]	0.09[a,b]	266.65[c]	211.87[c]
P	12	0.45[b]	<0.01[a]	0.09[a,b]	36.47[c]	29.07[c]
K	12	0.17[b]	<0.01[a]	0.09[a,b]	103.94[c]	71.57[c]

Means within the same row with different letter designations are significantly different ($p<0.05$).
[1]Geometric (Geo.) Mean

Most Desirable | Medium | Least Desirable

Conclusion: The <u>total adsorbed mass</u> of nutrients and metals attached to eroded material from composted areas less than 2% of that from soils

Vegetation & Weed Growth Sampling

Research Results

Vegetation Mass

Planted Species

Treatment	No.	Mean Mass of Planted Species (g/m^2)
Biosolids (A)	12	229.61[a]
Yard Waste (B)	12	338.90[a]
Bio-industrial (C)	12	366.44[a]
Control (P)	6	353.97[a]
Topsoil (T)	6	293.66[a]

Means within the same column with different letter designations are significantly different ($p<0.05$).

Most Desirable | Medium | Least Desirable

Conclusion: First season growth of planted species the same for all composts and soils.

Research Results
Vegetation Mass
Weed Species

Treatment	No.	Mean Weed Mass (g/m^2)
Biosolids (A)	12	33.90[a]
Yard Waste (B)	12	74.62[a]
Bio-industrial (C)	12	93.70[a]
Control (P)	6	353.14[b]
Topsoil (T)	6	260.45[b]

Means within the same column with different letter designations are significantly different ($p<0.05$).

Most Desirable | Medium | Least Desirable

Conclusion: First season growth of <u>weeds</u> much <u>lower</u> in test areas <u>blanketed</u> with compost

Compost vs.. Other Stormwater & Erosion Control Practices?

- Many good erosion control demonstration projects in U.S.
  - Cal Trans
  - Tex DOT
  - Connecticut DOT
  - Mn DOT
- But, NOT a lot of scientific studies rigorously comparing practices .... need more !
  - Example: Study by Faucette et.al. comparing compost blankets with hydro seeding

Compost Blankets vs. Hydroseed + berm or silt fence

Total runoff volume (mm) n=3

	Day one	Three months	Twelve months
Treatment	Average	Average	Average
PLC/mulch/gypsum	32.0ab	5.0c	15.9c
Biosolids compost	38.1ab	9.6c	21.6bc
MSW* compost/mulch	22.5b	1.8c	21.9bc
Yardwaste compost	33.0ab	8.1c	25.0abc
Hydroseed/mulch berm	36.7ab	20.2bc	34.2ab
Hydroseed/silt fence	30.0ab	32.3ab	27.6abc
Bare soil (not seeded)	42.3a	45.9a	40.8a

Most Desirable | Medium | Least Desirable

Evaluation of stormwater from compost and conventional erosion control practices in construction activities*.** L.B. Faucette, C.F. Jordan, L.M. Risse, M. Cabrera, D.C. Coleman and L.T. West., ***Journal of Soil and Water Conservation 60.6 (Nov-Dec 2005): p288(10).

Compost Blankets vs. Hydroseed + berm or silt fence

Average time (minutes) until start of runoff n = 3

	Day one	Three months	Twelve months
Treatment	RO start	RO start	RO start
PLC/mulch/gypsum	12.0bc	41.0ab	21a
Biosolids compost	8.3bcd	32.7b	23.7a
MSW* compost/mulch	20.0a	51.7a	14.3a
Yardwaste compost	13.0b	33.3b	14.7a
Hydroseed/mulch berm	7.3cde	14.3b	9.0a
Hydroseed/silt fence	6.0de	8.0b	10.3a
Bare soil (not seeded)	2.7e	6.3b	3.7a

Most Desirable | Medium | Least Desirable

Evaluation of stormwater from compost and conventional erosion control practices in construction activities. L.B. Faucette, C.F. Jordan, L.M. Risse, M. Cabrera, D.C. Coleman and L.T. West., ***Journal of Soil and Water Conservation*** 60.6 (Nov-Dec 2005): p288(10).

Compost Blankets vs. Hydroseed + berm or silt fence

Average total solids loss (mg) n = 3

	Day one	Three months	Twelve months
Treatment	Average	Average	Average
PLC/mulch/ gypsum	158.9b	14.6b	10.8b
Biosolids compost	105.8b	18.9b	8.8b
MSW* compost/ mulch	191.9b	6.0b	17.8b
Yardwaste compost	88.5b	13.7b	17.1b
Hydroseed/ mulch berm	265.1b	78.1b	10.9b
Hydroseed/ silt fence	307.9b	219.6b	14.5b
Bare soil (not seeded)	6428.1a	5464.2a	1109.7a

Evaluation of stormwater from compost and conventional erosion control practices in construction activities. L.B. Faucette, C.F. Jordan, L.M. Risse, M. Cabrera, D.C. Coleman and L.T. West., ***Journal of Soil and Water Conservation*** 60.6 (Nov-Dec 2005): p288(10).

Compost Blankets vs. Hydroseed + berm or silt fence

Average nitrate-N load (mg/m^2) n = 3

Treatment	Day one	Three months	Twelve months
Poultry	526.8bc	2.9a	4.7c
Biosolids	2568.3a	126.1a	9.7bc
MSW*	3.4d	8.5a	5.7c
Y waste	88.2cd	6.8a	8.4bc
H/Berm	796.4b	64.3a	15.4ab
H/fence	644.3b	171.6a	13.8abc
Bare soil	53.4cd	60.1a	20.1a

Most Desirable | Medium | Least Desirable

Evaluation of stormwater from compost and conventional erosion control practices in construction activities. L.B. Faucette, C.F. Jordan, L.M. Risse, M. Cabrera, D.C. Coleman and L.T. West., ***Journal of Soil and Water Conservation*** 60.6 (Nov-Dec 2005): p288(10).

Compost Blankets vs. Hydroseed + berm or silt fence

Average dissolved reactive P (mg/m^2) n = 3

Treatment	Day one	Three months	Twelve months
Poultry	75.3c	13.4a	13.7b
Biosolids	141.2bc	51.4a	37.8a
MSW*	2.7c	3.9a	7.4b
Y waste	56.5c	7.7a	9.7b
H/Berm	865.6a	20.3a	13.8b
H/fence	412.0b	26.7a	12.8b
Bare soil	0.54c	0.33a	19.4ab

Most Desirable | Medium | Least Desirable

Evaluation of stormwater from compost and conventional erosion control practices in construction activities. L.B. Faucette, C.F. Jordan, L.M. Risse, M. Cabrera, D.C. Coleman and L.T. West., ***Journal of Soil and Water Conservation*** 60.6 (Nov-Dec 2005): p288(10).

Final Thoughts

- Blanket applications of compost are very effective in reducing runoff
  - relatively coarse texture of composts retains surface infiltration capacity and helps to hold water on surface
  - due to high organic matter content....internal water-holding capacity is high
  - runoff is both reduced and delayed ..... most storms are over before composted areas even start to produce runoff

- Blanket applications of compost also greatly reduce erosion
  - mulching effect prevents raindrop impact that initiates erosion
  - very low runoff rates result in low sheet erosion
  - no sheet erosion ..... no rills or rill erosion !

Final Thoughts

- Protection offered by compost blankets is immediate .... no need to wait for vegetation to grow
  - particularly useful for runoff and erosion control on “late-season” construction projects

- Although some composts contain elevated levels of heavy metals or nutrients, only a small percentage of these pollutant are released from composted areas ..... often less than from bare soil (due to very low runoff and erosion)

Final Thoughts

- Composts aid rapid establishment of permanent vegetation

- Compost blankets can help to suppress 1st season weed growth ….. potentially reducing need for herbicide applications

Final Thoughts

- Avoid placing un-anchored compost in locations where high velocity flow .... ditches .... roof discharge areas .... steep slopes etc. is likely to occur
  - low bulk density of most composts make them vulnerable to floatation
  - use compost “logs” or “socks” to anchor composts when used in concentrated flow area

Final Thoughts

- All composts are NOT the same.
  - learn about the characteristics of different composts in produced your area
  - apply them appropriately ..... some are good for high value landscaping .... some for general soil amendment ..... some for erosion control

- To help insure consistent performance .... develop and follow appropriate compost specifications for different tasks.

Project Website
www.abe.iastate.edu/compost