ANALYSIS OF COMPOST TREATMENTS TO ESTABLISH SHRUBS AND IMPROVE WATER QUALITY

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Brent G. Hallock, Ph.D., CPSS, and CPESC, is a professor at California Polytechnic State University (Cal Poly), San Luis Obispo, since 1979. He teaches an undergraduate course in Soil Erosion and Water Conservation, an upper division course in Rangeland Resources, and a graduate course in Environmental Assessment for Erosion Control. He has taught over 35 seminars and short courses in site analysis, erosion control, and selection of management measures. His research grants with Caltrans, RWQCB and EPA total over three million dollars in the past 8 years.

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Anne Power performs research for the Vegetation Establishment and Maintenance Study, Earth and Soil Sciences Department at California Polytechnic State University, while completing her M.S. degree in general agriculture, with emphasis in Restoration and native California vegetation.

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Steven Rein, Ph.D. is an associate professor in the Statistics Department at California Polytechnic State University. Between receiving his Ph.D. in 1993 from U.C. Berkeley and coming to Cal Poly in 1998, he was an assistant professor at Virginia Commonwealth University in Richmond, Virginia. His primary area of research interest is in the application of statistical methodology to problems in ecology and biological sciences.

Michael Curto

Michael Curto earned an M.S. in Biological Sciences and a B.S. in Ecology and Systematic Biology from California Polytechnic State University. His interests and experience center on plant biogeography, ecology, and systematics, especially of Western North American grasses. As a consultant to the Utah Department of Transportation (UDOT), he designed and constructed RoadVeg, their statewide inventory or roadside vegetation (now a GIS) and performed field inventories of over 2500 miles of Utah roadways.

Misty Scharff

Misty Scharff has been involved with California State University Sacramento, performing research in erosion and sediment control for the California Department of Transportation since 2000. She received her M.S. and B.S. degrees in Soil Science from the California Polytechnic State University, where she assisted in numerous erosion control research studies. She has been a member of IECA since 1996.

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ABSTRACT

Utilization of compost as an erosion control tool is gaining momentum for many reasons. Compost offers excellent surface protection for reducing topsoil loss while providing a favorable substrate for hydroseed mixes. Soil moisture is retained and nutrients for vegetation are provided, meanwhile inhibiting undesirable plant species. However, there is wide variation in available compost sources and cost. Possible interactions between compost composition, soil type and vegetation production may occur. Hence, an experiment aimed to determine whether there is a noticeable difference in erosion control and seedling germination performance between several common types of compost applied at varying rates and methods over two subsoils was established.

The experiment was conducted at the Erosion Research Facility at California Polytechnic State University, San Luis Obispo, in conjunction with the California Department of Transportation, and the Office of Water Program at California State University, Sacramento. Fine sandy loam and silty clay subsoils were collected from two California highway construction sites. Test boxes were filled with one of the two soils, compacted, and positioned at a south-facing 2H:1V slope. After compost application, a hydroseed mix of four California native shrubs, *Baccharis pilularis, Eriogonum fasciculatum*, *Eriophyllum confertiflorum*, and *Lotus scoparius*, were seeded on the test boxes. Applications of the three composts included 1) topical 16 mm depth, 2) an admixture of soil and compost (25% by volume), as well as hydroseeding (finest textured compost only) at 3363 kg/ha with 1121 kg/ha fiber, 3) natural rainfall collected from boxes was analyzed for total water runoff, sediment load, sediment concentration, pH, total dissolved salts, and turbidity. In terms of water quality, all compost treatments performed significantly better than the control. Direct surface application consistently produced better water quality than mixed compost/soil application, yet mixing compost with the sandy clay loam produced more native shrubs.

Key Words: erosion control; compost; vegetation establishment; seeding native shrubs; water quality

EXPERIMENT TOPIC

Woody vegetation is a preferable plant palate for long-term erosion control on many sites, especially those with exposed, poor soils and rocky slopes and those in existing shrubland communities. Shrubs have much deeper rooting depths than herbaceous vegetation, pleasant aesthetics, low maintenance requirements, and provide excellent habitat for pollinating insects and avian fauna. A previous experiment demonstrated low success with germination of shrubs from seed in combination with herbaceous vegetation, presumably due to competition effects, as well as the inability to germinate when applied under a thick layer of physical erosion control treatment (Caltrans, 2001). In this experiment, shrubs were seeded, with no addition of grass or forb seed and very minimal existing seedbank, to test for germination with little competition.

Shrub cover may increase with the addition of compost treatment, while increasing water quality. The utilization of compost alone as an erosion control treatment has been identified as an effective means of reducing sediment loss (Caltrans, 2005). Although textbook definitions of compost are similar, a survey was conducted that compared compost sources from many areas of California. There is high variability in terms of compost nutrient content and particle size for composts of different feedstocks, and even for compost of the same feedstocks from different times of year. In depth studies have not been on the interaction between compost types and applications with vegetation cover and erosion control.

This study evaluated various types, rates, and application methods of compost and its effect on erosion control and shrub cover. Runoff, sediment loss, sediment concentration, and vegetation cover were studied with compost from three sources, with three application techniques on two subsoil types.

PROJECT OVERVIEW

The Vegetation Establishment and Management Study at the Erosion Research Facility at California Polytechnic State University (Cal Poly) San Luis Obispo, in conjunction with the California Department of Transportation and with the Office of Water Programs (OWP) at California State University, Sacramento, seeks to develop principles for erosion control through the use of various techniques for the short-term containment of soil, and to provide long-term plant cover. Both native and exotic vegetation will be analyzed for use in reducing soil loss and improving water quality.

EXPERIMENT RELEVANCE

From November 2004 through March 2005, an experiment was conducted that had direct relevance to projected revegetation during phases of a highway construction site in San Luis Obispo County, Calilfornia.

Given the arid climate and contracted season of favorable growing temperatures in conjunction with adequate rainfall, planned revegetation is inherently precarious at best. The roadside construction project will necessitate erosion control and revegetation measures on several challenging cut and fill slopes in this unpredictable environment.

GOALS

The goal of this experiment was to:

- Establish native shrub vegetation for long term soil surface stabilization;
- Ascertain the effects of compost type on water quality and vegetation;
- Statistically evaluate compost application rates and methods that reduce soil loss and maintain water quality.

OBJECTIVES

The objective of this experiment was to compare the effects of various *compost categories*: 1) a yard-waste, biosolid based, 2) a manure-based 3) and a commercial, humified, fine organic mixture; as well as the *application method*: a) applied topically at 16 mm, b) as a 25% mixture with the soil, or c) hydroseeded with fiber totaling 2mm, 8 mm, or 16 mm depth, on improved water quality and increased establishment of California native shrubs on silty clay and sandy clay loam soils.

DESIGN

Test boxes were positioned in rows and oriented such that soil surfaces faced approximately 165° south for adequate sun exposure (see Figure 1).

Test Boxes

The pressure-treated wood test boxes measured 2.0 m (6.6 ft) x 0.6 m (2 ft) x 0.3 m (1 ft), conforming to field plot tests conducted by Pearce et al. (1998). A metal mesh grate formed the base of the boxes, and silt fabric lined the inside to minimize soil loss. Boxes were positioned at a 2H:1V slope on supports. A one-ton chain hoist was used to move boxes when necessary.

A length of vinyl gutter and a 7.6 L (8 qt) plastic collection container was used to collect runoff from the base of each erosion test box. A rectangular piece of synthetic pond liner was cut and riveted to the vinyl gutter to prevent direct rainfall from entering the erosion collection system.

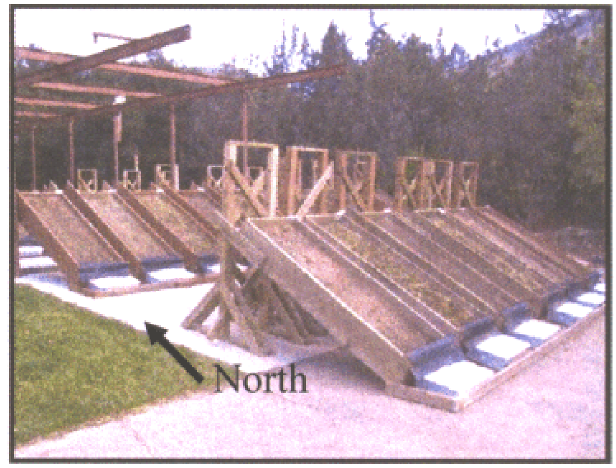

Figure 1. Site and test box setup.

Test Soils

Two types of subsoil were collected by department personnel from a road cut adjacent to the site of construction. Soil was compacted in the test boxes to at least 90% (calculated from bulk density), as typically required for construction fill (Caltrans, 2002). Soils were labeled S1 and S2; properties are listed in Figure 2.

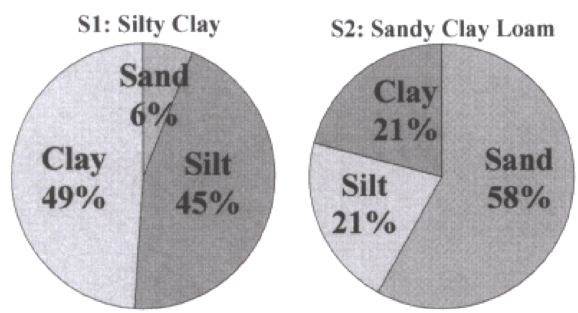

Figure 2. Test soil properties.

RUNOFF DATA COLLECTION AND ANALYSES

Runoff was analyzed for sediment load, pH, dissolved salt concentration (total dissolved salts/electrical conductivity) and turbidity (NTU). Dissolved salt concentration and pH were measured with a pH/EC/TDS/Temperature meter. In measuring NTU, samples were diluted to 500 parts per million if

Figure 3. Sandy clay loam (S2) left, silty clay (S1) right.

normal values were exceeded, and then calculated to comparative values.

Total sediment was analyzed using a procedure that combined methods described by ASTM D3977-97 (ASTM 2002) and EPA Method 160.2 (EPA 2001). Runoff was collected and any remaining sediment on the walls or bottom of the storage container was rinsed with de-ionized water. After each sample was weighed, 10–20 ml of 1 M $AlCl_3$, a common water treatment flocculent, was added to settle sediment. The container with sediment was oven dried at 115 ° C (239 ° F) for 24–48 hours, and dehydrated sediment was weighed.

Total water runoff was converted from g to L, and container weight and sediment weight values were subtracted to obtain runoff volume and total sediment amount (mg). Sediment concentration (mg/L) was calculated from these values.

Total runoff (L), total sediment (mg), and sediment concentration (mg/L), pH, total dissolved salt concentration and turbidity were analyzed via ANOVA models, after necessary variance stabilizing transformations were applied to achieve normality for all responses except pH. Treatment effects were compared with post-hoc procedure via Bonferroni adjustment of the individual error rate (Devore, 2003). Ratings of treatment performance were further compared with Main Effects Plots.

VEGETATION DATA COLLECTION AND ANALYSES

Plant identification (following Hickman, 1993), density and cover estimations were conducted 90 days after the experiment began (Nov.) at two 30-day intervals (Feb. and Mar.). Density and cover were estimated using a 0.3 m x 0.3 m square parcel (Figure 4) positioned on the upper and lower halves of each box, utilizing a modified point-transect method.

Figure 4. Vegetation analysis quadrant.

WEATHER DATA

Natural rainfall was measured and recorded by a weather station computer (Figure 5), and by backup rain gauges onsite. Additional data were available from California Irrigation Management Information System (CIMIS) and National Oceanic and Atmospheric Administration (NOAA).

Monthly precipitation totals over the duration of the experiment were higher in December, January, and February than the 56 year average (Figures 6 and 7). Rainfall was near record highs during the season.

With substantial rainfall, irrigation was not necessary. There were no simulated storm events; the data collected were from natural rainfall only. Rainfall

Figure 5. Weather station.

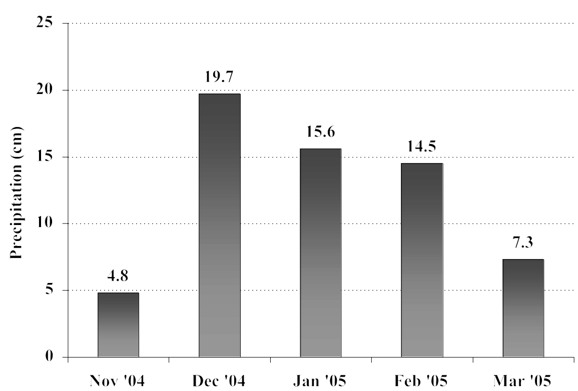

Figure 6. Monthly precipitation totals (cm), experiment duration.

data for 18 storms in which runoff was collected are listed in Table 1.

Moderate temperatures were experienced over the experiment season, which were conducive to plant growth (Table 2).

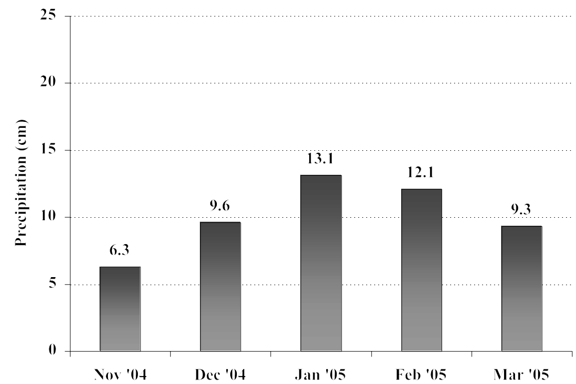

Figure 7. Fifty-six year average monthly precipitation (cm), experiment duration.

Table 1. Natural Rainfall Amounts for the Duration of Experiment.

Storm	Date	cm
1	7 Dec. 04	3.21
2	27 Dec. 04	0.81
3	29 Dec. 04	5.89
4	30 Dec. 04	0.41
5	31 Dec. 04	2.64
6	11 Jan. 05	0.25
7	26 Jan. 05	0.81
8	28 Jan. 05	2.03
9	11 Feb. 05	0.91
10	15 Feb. 05	0.53
11	18 Feb. 05	1.27
12	20 Feb. 05	1.04
13	21 Feb. 05	3.53
14	22 Feb. 05	1.27
15	27 Feb. 05	0.3
16	20 Mar. 05	0.53
17	22 Mar. 05	6.45
18	23 Mar. 05	0.48
	Total	**32.36**

METHODS

Ten test boxes were filled with silty clay (S1), and ten with sandy clay loam (S2). Ten erosion control treatments were applied to each soil type with no replications. Boxes were randomly numbered and

Table 2. Cal Poly, San Luis Obispo, Average Temperatures, Experiment Duration.

Month	Avg High Temp (°C)	Avg Low Temp (°C)
Nov. 04	17	6
Dec. 04	16	6
Jan. 05	16	6
Feb. 05	16	7
Mar. 05	17	7

positioned to assure unbiased assignment of each treatment.

The composts can be described as a yard waste-based biosolid with large woody pieces, ranging from approximately 8 to 20 cm, a manure-based fine textured organic with no woody material, and a commercially-purchased fine, humified, broken down product with approximately 1 cm wood particles, typically specified for the department. The latter product can be applied with hydroseed mix.

Topical treatments of compost (EC 3, 5, and 7) were applied as a 16 mm layer spread over the compacted soil surface. Admixture treatments of compost (EC 2, 4, and 6) consisted of 25% compost by volume mixed with soil and spread over compacted soil surface (Table 3).

Hydroseeding treatments (EC 8, 9, and 10) consisted of 1120 kg/ha (1000 lbs/ac) fiber, 3360 kg/ha (3000 lb/ac) commercial compost, and water. Each treatment received the same rate of material at 1 cm/sec (2 ft/min), but the number of passes varied to achieve a thicker depth. The process of hydroseeding is aimed at application on large areas and the force of the slurry output is very high. Since this would greatly enhance soil loss on the small area of the boxes during application, this experiment utilized a hand application method of hydroseed mix. Ingredients were combined in a large container and were continuously agitated. Small amounts of the solution were cast upon the soil surface to achieve the required depth and coverage.

Table 3. EC Treatments.

Label	Treatment	Method
EC1	None (Control)	None
EC2	Yard-waste-based Mixed	Admixture of upper 8 cm soil and compost (25% by vol).
EC3	Yard-waste-based Topical	16 mm topical application on soil surface.
EC4	Manure-based Mixed	Admixture of upper 8 cm soil and compost (25% by vol).
EC5	Manure-based Topical	16 mm topical application on soil surface.
EC6	Commercial Mixed	Admixture of upper 8 cm soil and compost (25% by vol).
EC7	Commercial Topical	16 mm topical application on soil surface.
EC8	2 mm depth Hydroseed	Hydroseeded *Commercial* at a rate of 3363 kg/ha with fiber at a rate of 1121 kg/ha, 2 passes at 1 cm/sec (2 ft/min) to achieve a 2 mm depth.
EC9	8 mm depth Hydroseed	Hydroseeded *Commercial* at a rate of 3363 kg/ha with fiber at a rate of 1121 kg/ha, 8 passes at 1 cm/sec (2 ft/min) to achieve a 8 mm depth.
EC10	16 mm depth Hydroseed	Hydroseeded *Commercial* at a rate of 3363 kg/ha with fiber at a rate of 1121 kg/ha, 16 passes at 1 cm/sec (2 ft/min) to achieve a 16mm depth.

Seed Mix

After compost and/or hydroseed treatments were applied, seed was applied with 1815 kg/ha (1500 lb/ac) of fiber and water. The seed mix contained California native woody plants commonly found in San Luis Obispo County. These shrubs are common pioneers on disturbed sites and are considered highly drought tolerant. Seeding rates are listed in Table 4.

DISCUSSION

In a sense our study was twofold: a survey was conducted of compost sources in California, determining common ingredients and processing methods; secondly, compost from three sources was tested along with application method and seeding of

Table 4. California Native Shrub Species Seeded and Seeding Rates.

Scientific Name	Common Name	PLS/m²	kg PLS/ha
Baccharis pilularis	Coyote Brush	323	0.3
Eriogonum fasciculatum	California Buckwheat	323	3.3
Eriophyllum confertiflorum	Coastal Golden Yarrow	323	0.5
Lotus scoparius	Deer Weed	323	3.3

native shrubs. When compared to the control (no added compost), all composts and application methods examined in this experiment improved water quality and increased seeded vegetation (note opaque runoff in Figure 8).

Figure 8. Sandy clay loam (S2) control (EC1) high sediment.

Although the long-term effects of this experiment cannot yet be deciphered, it may be extrapolated that shrubs have the ability to provide long-term cover and erosion control benefits. Therefore, the fact that shrubs germinated from seed and began to establish vegetation cover is encouraging for this type of treatment.

RESULTS

Topical applications and hydroseed treatments have been found to provide erosion control benefits by protecting the soil surface from raindrop splash and overland flow. It was found in previous experiments that a thick application of compost (approximately 5 cm) reduced weed invasion. Added seed in the form of hydroseed or direct seeding must be applied over the compost layer for effective germination.

Although more soil surface is exposed when mixing compost into the upper soil layer, infiltration should be increased, surface flow should be reduced, and soil structure should be improved.

On both soils, topical application of compost performed better statistically overall than mixed. Topical produced lower runoff, lower total sediment, and lower sediment concentration in the runoff, as well as lower pH, and lower turbidity, but higher total dissolved salts. Although a significant difference was not noted in shrub cover between the two methods, weed cover was lower with topical application.

Compost materials performed similarly when combined with soil. There was a slightly lower total sediment yield on sandy clay loam with mixed yard-waste-based and mixed manure-based, compared to mixed commercial, and higher shrub cover on mixed manure-based and mixed commercial, compared to mixed yard-waste-based.

Although hydroseed produced moderate runoff (all depths were similar), sediment was greatly reduced. A 16 mm depth proved more effective at sediment reduction than 2 mm depth (the bottom of container in Figure 8 can easily be seen). pH was similar between depths, but total dissolved salts and turbidity were reduced with a thicker depth (16 mm). However, 8 mm depth was overall better for good shrub production and low weed production.

On silty clay, topical yard-waste-based was best for low runoff, all performed well for total sediment reduction, yet 16 mm depth hydroseed provided the lowest sediment concentration. pH values were similar for all composts, but 16 mm depth hydroseed yielded slightly lower total dissolved salts and lower turbidity than the other topical composts.

On sandy clay loam, topical commercial was best for low runoff; topical manure-based, topical Commercial and 16 mm depth hydroseed all reduced total sediment, and topical manure-based yielded the lowest sediment concentration in runoff. Topical yard-

Figure 9. Sandy clay loam (S2) with 16 mm hydroseed (EC 10): low sediment.

waste-based produced slightly lower pH values, while 16 mm depth hydroseed produced the lowest total dissolved salts and turbidity.

Shrub germination may have been enhanced by low weed competition, as well as soil moisture retention. All three composts most likely provided both of these attributes. On silty clay, topical commercial provided the highest shrub cover and the lowest weed cover (Figure 10). On sandy clay loam, topical manure-based and topical commercial both provided high shrub cover and low weed cover. The commercially purchased native shrub seed contained weed seeds as well, thus adding weeds to the experiment. It was possible that the compost was a seed source itself; especially since the yard-waste-based did not produce the highest shrub or lowest weed cover in any category. Possible weed sources are the existing seedbank (although an initial germination test performed by staff, showed little to no germination) and aerial deposition.

Figure 10. Silty clay (S1) commercial topical application (EC7). High shrub germination.

RESULTS SUMMARY

Runoff and Sediment

Effects Common to Both Soil Types

- Topical reduced runoff, total sediment, sediment concentration, and turbidity more than mixed.
- No statistical differences were noted in performance between mixed composts.
- Runoff volumes were similar between hydroseed depths.
- A 16 mm depth hydroseed produced lower total sediment and sediment concentration than 2 mm and 8 mm depths.
- A 16 mm depth hydroseeded produced low turbidity.

Effects Specific to Silty Clay

- Topical yard-waste-based produced low runoff.
- Total sediment yield was similar between mixed and topical.
- A 16 mm depth hydroseed produced low total sediment and sediment concentration.

Effects Specific to Sandy Clay Loam

- Topical commercial produced low runoff.
- Mixed yard-waste-based and mixed manure-based produced low total sediment.
- Topical manure-based yielded low sediment concentration.

Vegetation

Effects Common to Both Soil Types

- Shrub cover was similar between topical and mixed.
- Mixed manure-based and mixed commercial produced higher shrub cover than mixed yard-waste-based and various hydroseed depths.

Effects Specific to Silty Clay

- Topical commercial produced the highest shrub cover.
- An 8 mm depth hydroseed produced high shrub germination.
- Topical produced lower overall weed cover than mixed.
- Commercial produced lower weed cover when mixed or topical.
- An 8 mm depth hydroseed produced the lowest amount of weeds compared to 2 mm and 16 mm depths.

Effects Specific to Sandy Clay Loam

- Topical manure-based and topical commercial produced high shrub cover.
- All hydroseed depths rated similarly in shrub cover.
- Topical and mixed application produced similar weed cover.
- Commercial produced low weed cover when topical or mixed.
- A 2 mm and 8 mm depths hydroseed yielded low weed cover.

Table 5 provides a ranked evaluation of the six treatments over both soil types. Bear in mind that these are qualitative assessments based on estimation of main effects plots and also reflect response trends in these data concordant with past experiments. Low runoff, low sediment concentration, high shrub cover and low weed cover are considered "Good."

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Table 5. Ranked Evaluation of EC Treatment Effects on Each Soil Type.

Performance Rank: 3 = Good 2 = Fair 1 = Poor (Higher sub- and total score = Good)

Sed Conc = Sediment Concentration in Runoff	**Silty Clay**					**Sandy Clay Loam**					
	Runoff		Vegetation		*Sub*	Runoff		Vegetation		**Sub**	Total
	Total	Sed Conc	Shrub	Weed	*Score*	Total	Sed Conc	Shrub	Weed	**Score**	Score
EC1 (Control)	2	1	1	1	*5*	2	1	2	2	**7**	12
EC2 (Yard waste-based compost mixed with soil	**3**	2	1	2	***8***	**3**	2	1	1	**7**	15
EC3 (Yard waste-based compost surface application)	**3**	2	2	2	***9***	1	2	1	1	**5**	14
EC4 (Manure-based compost mixed with soil)	**3**	2	2	2	***9***	**3**	2	2	2	**9**	**18**
EC5 (Manure-based compost surface application)	2	2	1	2	*7*	2	**3**	2	**3**	**10**	17
EC6 (Commercial compost mixed with soil)	2	2	**3**	**3**	***10***	2	1	**3**	**3**	**9**	**19**
EC7 (Commercial compost surface application)	**3**	2	**3**	**3**	***11***	**3**	2	**3**	2	**10**	**21**
EC8 (2 mm depth of hydroseeded Commercial compost)	2	2	1	2	*6*	2	2	2	2	**8**	14
EC9 (8 mm depth of hydroseeded Commercial compost)	1	**3**	2	**3**	***9***	2	**3**	2	2	**9**	**18**
EC10 (16 mm depth of hydroseeded Commercial compost)	1	**3**	1	2	*7*	2	**3**	1	2	***8***	15

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