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# Performance of Erosion Control Treatments and Native Vegetation on Reapplied Topsoil

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## Authors:

**Brent Hallock,** Earth and Soil Sciences Dept., Cal Poly, San Luis Obispo
**Anne Power,** Earth and Soil Sciences Dept., Cal Poly, San Luis Obispo
**Steve Rein,** Earth and Soil Sciences Dept., Cal Poly, San Luis Obispo
**Misty Scharff,** Office of Water Programs, California State University, Sacramento

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Storm Water Program
CSUS Office of Water Programs
6000 J Street, Modoc Hall, Room 1001, Sacramento, CA 95819-6025

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# PERFORMANCE OF EROSION CONTROL TREATMENTS AND NATIVE VEGETATION ON REAPPLIED TOPSOIL

*Brent G. Hallock*, Ph.D.

Professor
Earth and Soil Sciences Department

*Anne Power*

Research Associate
Earth and Soil Sciences Department

*Steve Rein*, Ph.D.

Associate Professor
Statistics Department
California Polytechnic State University
1 Grand Avenue
San Luis Obispo, CA  93407

*Misty Scharff*, M.S.

Soil Scientist
Office of Water Programs
California State University
7801 Folsom Blvd., Suite 102
Sacramento, CA  95826

## BIOGRAPHICAL SKETCHES

*Brent G. Hallock*, Ph.D., CPSS, and CPESC

Brent G. Hallock 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 Soil Erosion and Sediment Control. Brent earned Cal Poly's highest award of Distinguished Teacher in 2000. He has taught over 35 seminars and short courses in site analysis, erosion control, and selection of management measures. Dr. Hallock's research grants with Caltrans, RWQCB and EPA on the use of vegetation in erosion control and water quality total over two million dollars in the past eight years.

*Anne Power*

Anne Power earned a B.S. degree in Environmental Horticultural Science with a minor in Land Rehabilitation at Cal Poly State University, San Luis Obispo, and has assisted with restoration projects in the county. She works with the Vegetation Establishment and Maintenance Study while completing her M.S. degree in Environmental Restoration.

*Steve Rein*, Ph.D.

Steven Rein is an associate professor in the Statistics Department at Cal Poly State University in San Luis Obispo, California. 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, where he held appointments in both the Mathematical Sciences Department and at the Center for Environmental Studies. His primary area of research is in the application of statistical methodology to problems in ecology and biological sciences. Past work includes an analysis of the relationship between environmental factors and California's Chinook salmon population and contributing to the development of Virginia's Environmental Quality Index (VEQI).

*Misty Scharff*, APSS, and CPESC

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 bachelor's and master's degrees in soil science from the California Polytechnic State University, San Luis Obispo, where she assisted in numerous erosion control research studies. She has been a member of IECA since 1996.

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## ABSTRACT

Two experiments were performed to test the effectiveness of topsoil in combination with erosion control methods at the Erosion Research Facility at California Polytechnic State University (Cal Poly) San Luis Obispo, in conjunction with the Office of Landscape Architecture of the California Department of Transportation (Caltrans) and with the Office of Water Programs (OWP) at California State University, Sacramento.

Test boxes, measuring 2.0 m x 0.6 m x 0.3 m, were filled with topsoil, either a gravelly clay loam or a fine sandy loam, collected from two highway construction sites. Soils were compacted to at least 95% and the boxes were set at a 2H:1V, south-facing slope. Total runoff, total sediment, water quality, and vegetation analysis were completed for each treatment.

The physical erosion control treatments in the first experiment were: soil roughening, jute netting, jute over 0.6 cm (0.25 in) compost, crimped straw, and crimped straw over 0.6 cm (0.25 in) compost. Natural rain was collected for 90 days. On both soils, jute with compost yielded high water quality. Jute netting, jute with 0.6 cm (0.25) compost, crimped straw, and crimped straw with 0.6 cm (0.25 in) compost all reduced sediment load. On the sandy loam, straw with compost had the least amount of runoff. The highest rating of grass growth was found on jute treatment on the clay loam, straw with compost on the sandy loam. The highest legume rating was found on jute with compost on the sandy loam.

The second experiment utilized hydroseeding with California natives *Achillea millefolium* (common yarrow) and *Bromus carinatus* (California brome), with: 1) seed *in* 1680 kg/ha (1500 lbs/ac) fiber with no compost, 2) seed *in* 1680 kg/ha fiber with 560 kg/ha (500 lbs/ac) compost, 3) seed *in* 1680 kg/ha fiber with 1680 kg/ha compost, 4) seed *over* 3920 kg/ha (3500 lbs/ac) fiber with 560 kg/ha compost, or 5) seed *under* 3920 kg/ha fiber with 560 kg/ha compost. Irrigation was applied, as there was no natural rainfall during this experiment. A simulated 50-year storm (2.54 cm/hr) was performed after 90 days. Although all treatments reduced runoff and sediment load, seed *over* 3920 kg/ha with 560 kg/ha compost yielded the highest reduction. The clay loam yielded highest vegetation cover with seed *in* 1680 kg/ha fiber with no compost and the fine sandy loam yielded highest cover with seed *over* 3920 kg/ha fiber with 560 kg/ha.

**Key Words**: erosion control treatments; topsoil replacement; water quality; hydroseeding with California native species

## INTRODUCTION

Roadside revegetation projects present substantial challenges to successful development of desired plant associations and vegetation structure. Cut or fill slopes are often steeply inclined, highly compacted, and lacking topsoil (Montalvo et al., 2002). Excavated topsoil is sometimes stockpiled for reapplication of pre-existing organic matter, soil microbes, and seed as both an inexpensive means of erosion control, and as a method to re-establish vegetation consistent with the surrounding context. However, stockpiled seedbanks may include undesirable, weedy species that inhibit establishment of desired native species (D'Antonio and Meyerson, 2002).

As a surrogate for soil, typical surface application of organic matter (e.g., "hydromulch") provides both physical protection from raindrop erosion and a favorable seedbed for some desired natives. However, composition, source, and cost issues, as well as the initial nutrient imbalances and absence of beneficial soil microbes, may present problems with individual products.

To test the effectiveness of topsoil in combination with erosion control methods, two experiments were conducted at the Erosion Research Facility at California Polytechnic State University (Cal Poly), San Luis Obispo, in conjunction with the Office of Landscape Architecture of the California Department of Transportation (Caltrans), and with the Office of Water Programs (OWP) at California State University, Sacramento.

## GOAL

The goal was to compare erosion control treatments applied on clay loam and fine sandy loam topsoil and observe the overall affect these treatments have on runoff, sediment loss, water quality, and vegetation establishment.

In 2003–2004, two experiments, designated RS5 and RS6, were performed and will be discussed.

- RS5 objective: To compare the effects of physical erosion control treatments, soil roughening, jute netting, jute netting over 0.6 cm (0.25 in) of compost, crimped straw, and straw crimped over 0.6 cm of compost, on clay loam and fine sandy loam topsoils with existing seedbanks, and determine how these treatments and vegetation from the seedbank affect runoff, sediment loss, and water quality during natural rainfall.

- RS6 objective: To determine the effects of various rates of fiber and compost in a hydroseed mix on germination of the existing seedbank and germination of added California native seed on clay loam and fine sandy loam topsoils, and how these factors affect runoff, sediment loss, water quality, and vegetation cover under simulated rainfall.

## EXPERIMENTAL DESIGN

### Design Factors Common to RS5 and RS6

*Test Boxes*

The 24 test boxes measured 2.0 m x 0.6 m x 0.3 m and were set at a south-facing 2H:1V slope (Figure 1).

**Figure 1. Test boxes at 2H:1V south-facing slope.**

*Soil Types*

Two types of topsoil (Table 1) were collected from highway construction sites and applied to the boxes. Compaction was at least 95% (Caltrans, 2002), which was calculated from bulk density.

**Table 1. Soil Descriptions.**

| Abbr | Type | Site | Notes |
|---|---|---|---|
| S1 | Clay loam 42.5-30-27.5 | Eastbound SR 46 E, PM 39.9 | 5% small gravels (< 2.54 cm); 28% clay |
| S2 | Fine Sandy Loam 57-27-16 | Eastbound SR 46 E, PM 37.9 | < 2% small gravels (< 1.27 cm); 16% clay |

*Vegetation Analysis*

Plant species were counted and recorded after 30 days, with nomenclature following Hickman (1993). At 60 days, percent cover was estimated using a modified Daubenmire Method (Daubenmire, 1959; Interagency Technical Team, 1996).

Each of the 24 boxes were divided into “upper” and “lower” sections, with random placement of a 25-quadrant square in each area. For each quadrant, an observation was made of the total percent cover in each cover class of interest. RS5 cover classes were: grass, legume, other forb, compost, straw, and bare soil. RS6 cover classes were: grass, legume, yarrow, other forb, litter, and bare soil. A ranking system was applied with a number representing a range of percentage cover (Table 2).

**Table 2. Vegetation Ranking System.**

| Ranking | Range - % Cover |
|---|---|
| 1 | < 1 |
| 2 | 1–5 |
| 3 | 6–25 |
| 4 | 26–50 |
| 5 | 51–75 |
| 6 | 76–95 |
| 7 | 96–100 |

*Water Quality Analysis*

Total runoff was weighed and converted from g to L. The pH was measured using a Corning pH 240 with a Fisher Accumet electrode. Following ASTM D3977-97 (ASTM, 2002) and EPA Method 160.2 (EPA, 2001), runoff was flocculated with 10–20 ml 0.1M $CaCl_2$. The water was removed after the sediment settled, oven dried at 105° C (220.8° F) for 24–48 hrs and weighed.

From the sediment (mg) and runoff (L) weights, sediment concentration (mg/L) was calculated.

*Statistics*

Vegetation cover, sediment concentration, total runoff, total sediment, and vegetation cover were analyzed via ANOVA, after necessary variance stabilizing transformations were applied to achieve normality. Treatment effects were compared with Tukey's HSD post-hoc procedure (Devore, 2003).

**RS5 Design: November 2003–February 2004**

*Procedure*

Twelve test boxes were filled with S1, and twelve with S2. Boxes were randomly numbered and placed in numerical order to assure indiscriminate placement of each treatment. One of six erosion control treatments was applied to each box, replicated on each soil (Table 3).

**Table 3. RS5 Erosion Control Treatments.**

| Abbr | Treatment |
|---|---|
| EC1 | No treatment (control) |
| EC2 | Soil roughening |
| EC3 | 2.54 cm (1 in) jute |
| EC4 | 2.54 cm (1 in) jute over 0.6 cm (0.25 in) compost |
| EC5 | Crimped certified weed-free straw |
| EC6 | Crimped certified weed-free straw over 0.6 cm (0.25 in) compost |

Treatment applications:

- EC1: No treatment was applied after compaction.
- EC2: The edge of a soil tamp was pressed into the soil at 20.32 to 25.4 cm (8 to 10 in) intervals.
- EC3 and EC4: Jute netting was cut to box size, placed on the soil surface and fastened with jute hooks.
- EC4 and EC6: Humified, fine, rich compost product was applied at recommended rate (Caltrans, 2003).
- EC5 and EC6: A rounded metal bar was used to press straw into the soil to simulate crimping (Caltrans, 1999).

The boxes were exposed to natural rainfall. Rain gauges and an on-site weather station recorded storm output, which was cross-referenced with data from the National Oceanic and Atmospheric Administration (NOAA, 2004) station on campus.

*Natural Rain Collection*

Natural rainfall flowed along the surface of the boxes and was collected into plastic containers at the base. After each storm, all the samples were collected and analyzed.

**RS6 Design: March 2004–August 2004**

*Procedure*

Plant material from RS5 and the upper 7.62 cm (3 in) of soil in the boxes were removed. S1 and S2 were replaced and the surface was slightly roughened (Caltrans, 2003).

The boxes were hydroseeded with seed, fiber, compost (if part of treatment), and water. Boxes not receiving treatment were covered with a waterproof tarp (Figures 2a and b).

The California native species seeded were *Achillea millefolium L.* (common yarrow) and *Bromus carinatus Hook & Arn.* (California brome). The seed selection

**Figure 2a. Hydroseeding 3/19/04.**

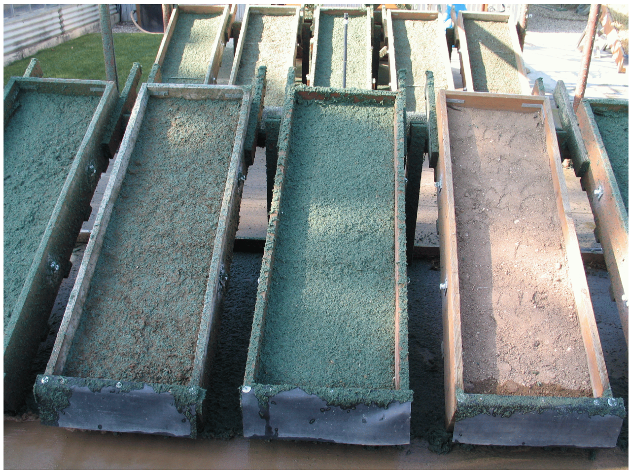

**Figure 2b. Boxes after hydroseeding.**

was based on availability, distribution throughout California, growth habit, and use in controlling erosion (Caltrans, 2001, v.2). Erosion control (EC) treatments are as follows (Table 4).

**Table 4. RS6 Erosion Control (EC) Treatments.**

| Abbr | Treatment |
|---|---|
| EC1 | No treatment (control) |
| EC2 | Seed *in* 1680 kg/ha (1500 lb/ac) fiber, with no compost |
| EC3 | Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 1680 kg/ha(1500 lb/ac) compost |
| EC4 | Seed *in* 1680 kg/ha (1500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost |
| EC5 | Seed *over* 3920 kg/ha fiber (3500 lb/ac) with 560 kg/ha (500 lb/ac)compost |
| EC6 | Seed *under* 3920 kg/ha (3500 lb/ac) fiber with 560 kg/ha (500 lb/ac) compost |

Based on typical rates, the seeding rates are shown in Table 5 (Caltrans, 2001, v.2).

*Irrigation*

Irrigation was applied three times per day for two minutes, as there was no rain during RS6.

*Rainfall Simulators*

The boxes were subjected to a California central coast 50-year storm simulation after 90 days. The two

**Table 5. Seed Rates in Hydroseed Mix.**

| Seed in Hydroseed Mix | Rate |
|---|---|
| *Bromus carinatus Hook & Arn.* (California brome) | 3.63 kg/ha (30 lb/ac) |
| Qty PLS/tankfull | 0.194 kg (0.43 lb) |
| Qty bulk seed/tankfull | 0.216 kg (0.476 lb) |
| *Achillea millefolium L.* (Common yarrow) | 0.907 kg/ha (2 lb/ac) |
| Qty PLS/tankfull | 0.013 kg (0.0286 lb) |
| Qty bulk seed/tankfull | 0.014 kg (0.032 lb) |

variable sweep Norton Rainfall Simulators equipped with 41 kPa (6 psi) spray nozzles produced drops averaging 2.25 mm (0.09 in) in size (Figure 3). Homogeneity of the nozzle output was tested prior to simulations and produced 95% uniformity.

**Figure 3. Rainfall simulators.**

The frequency/intensity pattern, simulating the west coast hydrograph model, was 15 min of low intensity rainfall, followed by 60 min of high intensity rainfall, then back to 15 min of low intensity rainfall, totaling 3.81 cm (1.5 in).

## RESULTS AND DISCUSSION

**RS5**: **November 2003–February 2004**

*Weather*

Rainfall was collected from November to mid-February. The highest amount of rainfall, 5.08 cm (2.0

in), was collected 02/02/04. Rainfall dates and amounts are as follows (Table 6).

**Table 6. RS5 Rainfall.**

| Storm Dates | Interval | Amount |
|---|---|---|
| 37932 | 0-day | 0.20 cm (0.08 in)* |
| 37936 | | 0.15 cm (0.06 in)* |
| 12/06/03–12/07/03 | 30-day | 0.86 cm (0.34 in) |
| 12/12/03–12/14/03 | | 1.24 cm (0.49 in) |
| 12/19/03–12/20/03 | | 0.69 cm (0.27 in) |
| 12/24/03–12/26/03 | | 3.91 cm (1.54 in) |
| 01/01/04–01/02/04 | 60-day | 2.82 cm (1.11 in) |
| 38018 | 90-day | 5.08 cm (2.0 in) |
| 38034 | | 2.79 cm (1.1 in)* |
| *Total* | | *17.74 cm (6.88 in)* |

(VEMS weather station; *NOAA, 2004.)

The average high temperature was 18.1° C (64.5° F) and the average low temperature was 5.4° C (41.8° F).

*Sediment Concentration*

A lower sediment concentration *overall* was noted on S1 compared to S2 (p = 0.035). Both S1 and S2 average sediment detachment decreased over time (Figures 4 and 5).

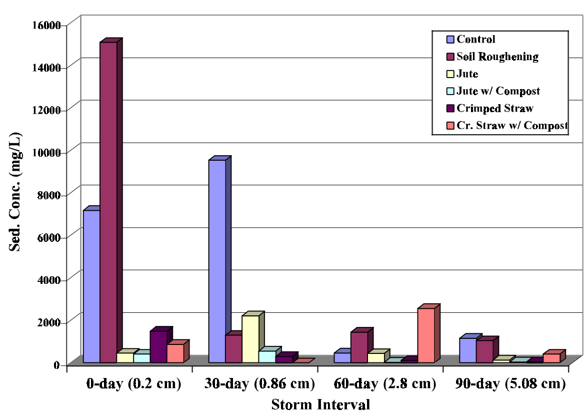


**Figure 4. S1 change in sediment concentration over time (four storms).**

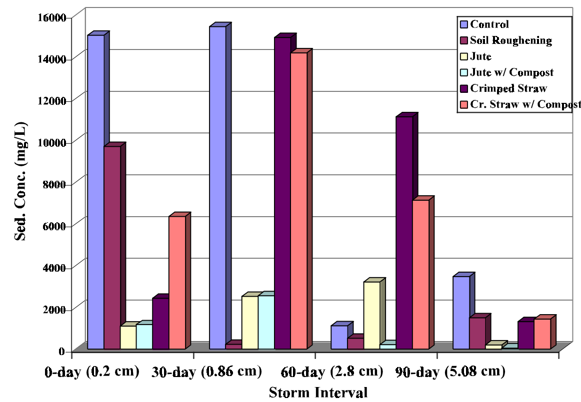


**Figure 5. S2 change in sediment concentration over time (four storms).**

On both S1 and S2, jute with compost generated the statistically lowest sediment concentration overall. The control, soil roughening, straw, and straw with compost produced statistically similar sediment concentrations overall.

*Total Runoff*

Overall, jute with compost discharged higher runoff than the control, straw, and straw with compost on S1 (Figure 6).

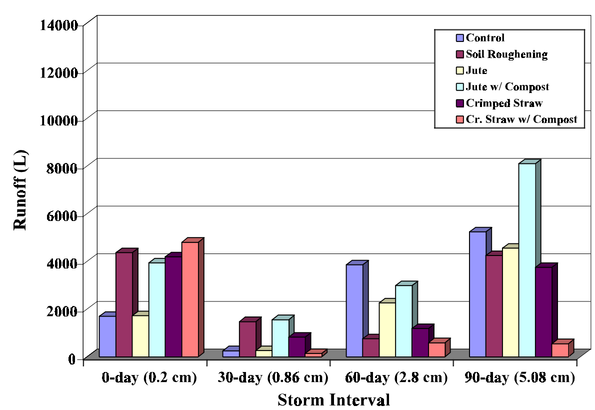


**Figure 6. S1 change in runoff over time (four storms).**

On S2, straw with compost generated the lowest amount of runoff. Jute, jute with compost, and straw alone yielded moderate runoff and the control and soil roughening yielded the highest (Figure 7).

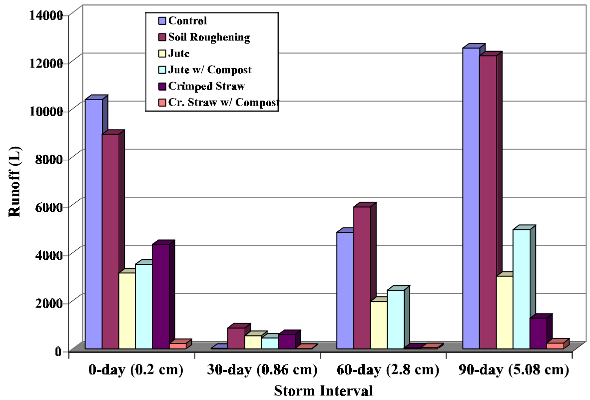


**Figure 7. S2 change in runoff over time (four storms).**

*Total Sediment*

Delivery of sediment load in runoff varied on soil type (p = 0.002). S1 had lower average sediment detachment than S2 across all treatments.

The treatments affected sediment loads (p = 0.003). On S1, the control and soil roughening performed similarly. Jute, jute with compost, straw, and straw with compost all performed better than the control and soil roughening (Figure 8).

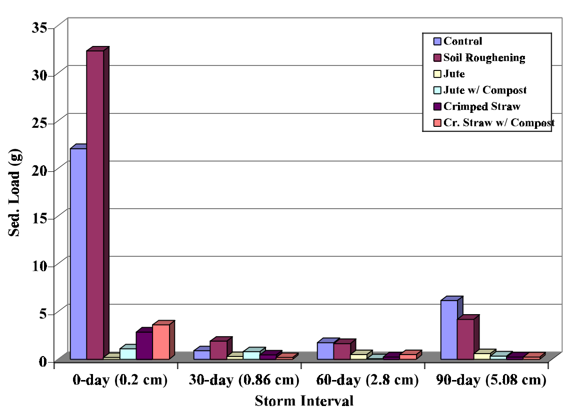


**Figure 8. S1 Change in sediment load over time (four storms).**

On S2, jute, jute with compost, crimped straw, and straw with compost had similar total sediment loads, which were much lower than the control and soil roughening (Figure 9).

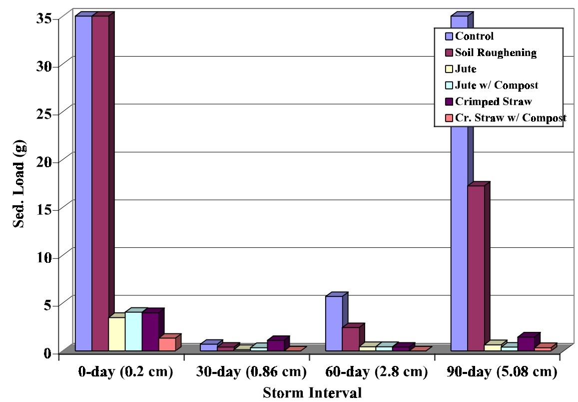


**Figure 9. S2 Change in sediment load over time (four storms).**

*Vegetation*

Germination began after 14 days. There was no significant difference between "upper" and "lower" quadrants of the box in legumes (p = 0.381) or grass (p = 171).

EC treatment had an effect on legume cover (p = 0.034) and grass cover (p = 0.013), but the effect of treatment depends on soil type for both legume (p = 0.004) and grass (p = 0.001).

The S1 control yielded the highest rating of legumes compared to the other treatments. Jute alone allowed for the most grass, followed by jute with compost and soil roughening.

On S2, jute with compost produced the highest amount of legumes. Straw with compost yielded the most grass, and was statistically different from soil roughening and jute with compost.

Although certified weed-free straw was used, *Hordeum vulgare* (cultivated barley) was found growing in the "straw" and "straw with compost" boxes. Presumably, this is the straw typed used, which contained some viable seed that contributed to the seedbank, and therefore the total grass cover.

*pH*

S1 runoff pH was higher than S2 ($p = 0.033$). For S1 and S2, pH was higher on the control and soil roughening compared to jute, jute with compost, straw, and straw with compost.

*Discussion*

Since S1 had lower sediment concentration than S2, this may indicate that an increase in clay and gravel decreases detachment and transport of sediment. Lower sediment concentration on both soils over time may be due to an initial loss of mobile soil particles that decrease with more rain. Jute, jute with compost, straw, and straw with compost all performed similarly, and all performed better than the control or soil roughening.

Although jute, jute with compost, straw, and straw with compost produced moderate amounts of runoff, the treatments yielded low amounts of sediment for both S1 and S2. Soil roughening loosened the soil and, in some instances, increased sedimentation and reduced cover was noted on this treatment. This implies that "safe sites" for seed germination were quickly filled in. Compaction in conjunction with roughening, i.e., track-walking, may have better performance.

Since no noticeable difference was noted in runoff, sediment load, and water quality between the jute with compost and straw with compost versus the treatments alone, it is possible that 0.6 cm (0.25 in) was not an adequate amount of compost to filter sediment. A thicker application of compost may have reduced sediment detachment, as found in an earlier experiment (Caltrans, 2003).

Compost may have provided nutrients on S2. The highest amounts of grass and legume growth were treatments (straw and jute) in combination with compost. Seed that may have been incorporated in the straw contributed to grass cover in the straw treatments.

**RS6**: **March 2004–August 2004**

*Weather*

NOAA rated March and April 2004 temperatures as "much above normal." The average high temperature was 26.9° C (75° F), reaching 39.5° C (103° F), and the average low temperature was 8.3° C (47° F). May and June temperatures were rated as "above normal," with the average high temperature at 26.6° C (79.8° F) and the average lows at 10.0° C (50° F) (NOAA, 2004).

*Sediment Concentration*

All physical treatments enhanced water quality compared to the control. On average, the log of sediment concentration was 2.16 units higher than the log of sediment concentrations for the other treatments ($p < 0.001$) (Figure 10). These treatments yielded similar sediment concentrations.


**Figure 10. Runoff collection bins: S1 control (left) and S1 seed *in* 1680 kg/ha fiber with no compost (right).**

*Total Runoff*

Seed *over* 3920kg/ha fiber with 560 kg/ha compost produced the lowest runoff and seed *under* 3920 kg/ha fiber with 560 kg/ha compost produced the second lowest.

*Total Sediment*

The control yielded a much higher amount of sediment than all other treatments. Seed *over* 3920 kg/ha fiber with 560 kg/ha compost generated the least amount of runoff, and seed *under* 3920 kg/ha fiber with 560 kg/ha compost produced the second lowest.

*Vegetation*

Germination began approximately one week after hydroseeding. Slow, sparse growth may have been due to higher than average spring temperatures. Species were almost solely weeds, dominated by *Brassica* spp./*Hirschfeldia* spp. (mustard), *Centaurea melitensis* (tocolote), *Erodium circatarium* (filaree), and *Melilotus officinalis* (yellow sweetclover).

A higher amount of vegetation established on all treatments compared to the control (Figure 11).

**Figure 11. Test boxes: S1 control (left) and S1 straw (right).**

A variety of grasses, including multiple *Bromus* spp., germinated, but few produced flower heads. Differentiation *B. carinatius* from other *Bromus* spp. was questionable; therefore, all grasses were included in the same category (Figure 12).

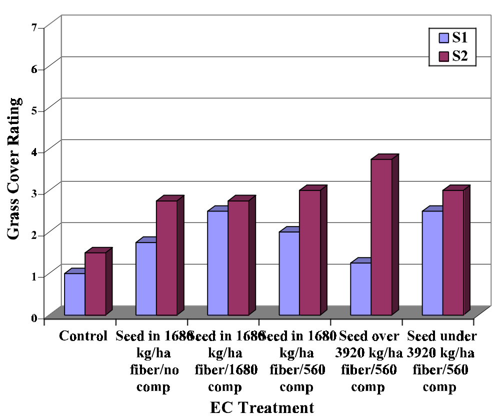


**Figure 12. S1 vs. S2 grass cover.**

*Lupinus* spp. (lupine) was found in S1 only, as were a higher number of legumes overall ($p < 0.001$) compared to S2. The control rated lowest in legume cover, followed by seed *over* 3920 kg/ha fiber with 560 kg/ha compost (Figure 13).

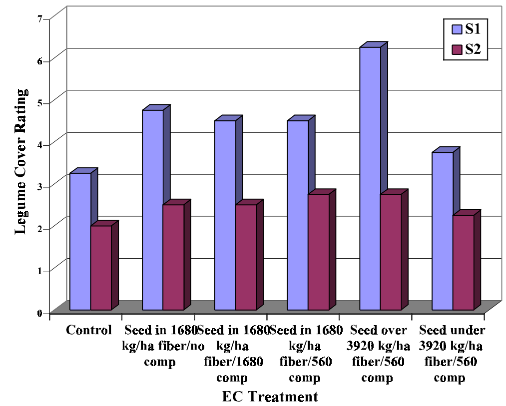


**Figure 13. S1 vs. S2 legume cover.**

Few common yarrow and California brome seeds germinated. Lower overall yarrow cover was found on S1 than S2. Yarrow cover was highest in S1 with seed *in* 1680 kg/ha fiber with 1680 kg/ha compost and highest in S2 with seed *over* 3920 kg/ha fiber with 560 kg/ha compost (Figure 14).

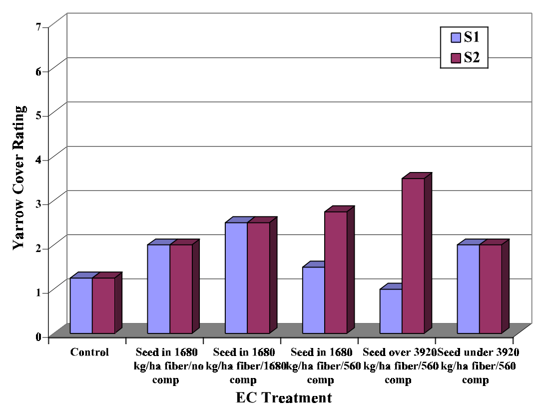


**Figure 14. S1 vs. S2 yarrow cover.**

S1 had lower levels of "other forb" than S2, and lower quadrants had less "other forb" than the upper quadrants (Figure 15).

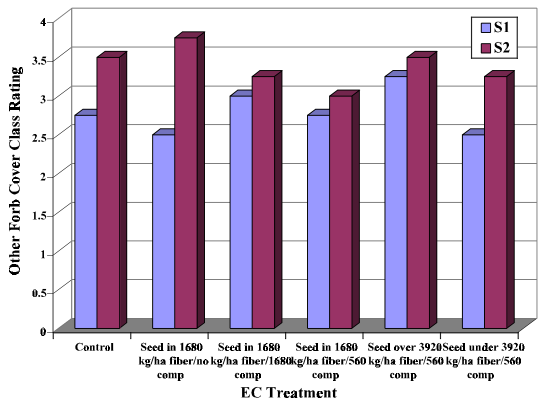


**Figure 15. S1 vs. S2 other forb cover.**

*pH*

There were no significant differences in runoff pH between the treatments.

*Discussion*

There were no significant differences between treatments on soil type.

No statistical differences were noted between compost rates (no compost, 560 kg/ha and 1680 kg/ha) in runoff, sediment load or water quality *at these composting rates*. Even at the highest rate, 1680 kg/ha, compost was difficult to visibly detect on the soil surface and did not provide complete cover.

The treatments delivered similar sediment concentrations, but seed *over* 3920 kg/ha fiber with 560 kg/ha compost and seed *under* 3920 kg/ha fiber with 560 kg/ha compost produced lower total water and total sediment. Trends show that seed *over* 3920 kg/ha fiber with 560 kg/ha compost performed better than seed *under* 3920 kg/ha fiber with 560 kg/ha compost, but the two were not statistically significantly different.

S1 comprised higher vegetation cover than S2. This may be due to either a greater number of seeds in the seedbank, or the higher fertility and water-holding capacity of clay compared to sandy soils was beneficial for vegetation.

More common yarrow was found on S2 compared to S1, possibly due to lower vegetation competition.

On S1, seed *in* 1680 kg/ha fiber with no compost seemed to encourage germination of common yarrow, while seed *over* 3920kg/ha fiber with 560 kg/ha compost promoted germination on S2.

Since yarrow exhibits relatively small seed size, seeding *under* 3920 kg/ha of fiber with 560 kg/ha of compost may have hampered germination. Seeding *over* fiber seemed to encourage germination on S2.

## CONCLUSIONS

The clay loam yielded lower average sediment than fine sandy loam. Sediment loss decreased over time. Although jute and jute with compost produced high runoff, the water quality was very excellent. Straw with compost reduced runoff on the sandy soil. Jute, jute with compost, straw, and straw with compost had decreased sediment loads compared to the control and soil roughening. Higher vegetation cover and much higher amount of legumes overall, was found on clay compared to sandy loam.

Although compost added at this low rate did not seem to affect runoff and water quality, the highest ratings of legume and grass were found with the compost treatments on the sandy soil. Therefore, compost possibly contributed fertility for increased growth.

Seed in straw may contribute to the seedbank.

All rates of hydroseeding increased water quality, decreased sedimentation, and increased vegetation when compared to the control.

Trends show that seed *over* 3920 kg/ha with 560 kg/ha compost reduced runoff. Yarrow germination was favored by seed *in* 1680 kg/ha fiber and 560 kg/ha compost on clay and seed *over* 3920 kg/ha fiber with 560 kg/ha compost on sandy loam.

## CONTRIBUTORS

Research Assistants
Laura Blazey, Earth Science Major
Danielle Castle, Environ. and Systematic Biol. Major
Ninah Rhodes, B.S., Environ. and Syst. Biol.
Christa Turner, Animal Science Major
Laura Unrue, Animal Science Major.

Technical Assistance
Michael Curto, M.S., Biological Sciences Department

Kaila Dettman, M.S., Watershed Hydrology and Soil Conservation

Craig Stubler, B.S., Technician Earth and Soil Science Dept.

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