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Effectiveness of Native Vegetation Planting Techniques to Minimize Erosion

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BIOGRAPHICAL SKETCHES

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Brent G. Hallock, Ph.D., CPSS, and CPESC, is a professor at California Polytechnic State University, San Luis Obispo, since 1979. He teaches courses in soil erosion and water conservation, rangeland resources, and 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. He has had 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 8 years.

Kaila Dettman

Kaila Dettman earned her M.S. degree in Watershed Hydrology and Soil Conservation, and her B.S. degree in Animal Science, with a concentration in Rangeland Resources, from Cal Poly State University. She is currently a research associate for the Vegetation Establishment and Maintenance Study funded by Caltrans.

Steve Rein

Steven Rein, Ph.D., is an associate professor in the Statistics Department at Cal Poly 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, where he held appointments in both the Mathematical Sciences Department and at the Center for Environmental Studies. His primary area of research interest is in the application of statistical methodology to problems in ecology and the biological sciences.

Michael Curto

Michael Curto earned a B.S. in Ecology and Systematic Biology from Cal Poly State University. His interests 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 database inventory of roadside vegetation (now a GIS) and performed field inventories of over 2500 miles of Utah roadways.

Misty Scharff

Misty Scharff works with California State University Sacramento performing research on erosion and sediment control for the California Department of Transportation. She received her B.S. and M.S. degrees in soil science from the Cal Poly State University, where she assisted in numerous erosion control research studies.

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ABSTRACT

Vegetation plays a key role in decreasing soil detachment and transport from project sites. Vegetation promotes long-term protection of the soil surface via leaf cover and root establishment, provides a viable alternative to many synthetic means of erosion control, increases biodiversity, and supplies aesthetic value to sites. However, native vegetation can be a challenge to establish in disturbed soils. Successful establishment relies on proper moisture availability, appropriate nutrient levels, adequate soil structure, and suitable planting techniques.

The California Department of Transportation, Office of Landscape (Caltrans), and the Office of Water Programs, California State University, Sacramento (OWP), conducted a study with the staff at the Erosion Research Facility at California Polytechnic State University, San Luis Obispo (Cal Poly) testing the performance of various planting techniques. This study compared flats or sod strips, plugs, hydroseed, and compost applications by measuring the effect of each on vegetative cover, erosion, and water quality.

The techniques were applied to boxes filled with clay loam soil and set at a 2H:1V slope. Combinations of techniques were: flats or plugs on top and toe, flats or plugs on toe only, and hydroseeding. Species composition of the flats and plugs included *Bromus carinatus* (California Brome) and *Achillea millefolium* (Common Yarrow). The boxes were exposed to natural rainfall recorded by an onsite weather station, as well as simulated rainfall that mimicked a 50-year storm event. Runoff was collected and analyzed for total runoff, sediment load, sediment concentration, pH, and salt concentration. Understory and overstory vegetative cover was measured using a modified transect method.

Planting on the top and toe removed 99% and 85% of the sediment produced by bare ground and hydroseeding alone, respectively. This suggests that successful establishment of vegetation on the top and toe is crucial. Flats consistently performed better than plugs, removing 80% more sediment and producing more native vegetative cover. Jute and compost decreased sediment load, but inhibited plant growth. Compost did not give native vegetation an advantage over weedy annual vegetation. Higher pH and salt concentrations were detected in the runoff from boxes treated with compost, but the levels were not harmful to plants.

Planting techniques greatly affect the success of vegetative establishment in removing sediment from runoff, increasing infiltration, and promoting vegetative cover. Therefore, careful consideration must be given to how vegetation is planted on construction sites and disturbed soils.

Key Words: erosion control; native vegetation establishment; water quality; composting; flats, plugs, and hydroseeding

INTRODUCTION

Vegetation plays a key role in decreasing soil particle detachment and transport from sites where the soil surface has been disturbed by human activities. Vegetation promotes long-term protection of the soil surface by providing leaf cover that intercepts precipitation and by establishing roots, which aid soil structure development, thereby increasing infiltration and soil stability. Vegetation also provides a viable alternative to many synthetic means of erosion control, increases biodiversity, and increases the aesthetic value of project landscapes.

Native vegetation can be difficult to establish in disturbed soils with low organic matter content, compaction, and aggressive weedy annual vegetation. Successful establishment relies on proper moisture availability, appropriate nutrient levels, adequate soil structure, and suitable planting techniques.

As part of a cooperative effort to improve methods of establishing native vegetation for erosion control and improving water quality, the California Department of Transportation (Caltrans), and the California State University, Sacramento, Office of Water Programs (OWP), conducted a study at the Erosion Control Research Facility at California Polytechnic State University, San Luis Obispo (Cal Poly) to test the performance of various planting techniques.

GOAL

This experiment sought to identify and compare planting techniques that provide immediate soil surface stability and long-term erosion control to reduce soil loss and improve water quality using native vegetation.

OBJECTIVES

- Identify planting techniques that promote long term establishment of native vegetation.
- Compare the effects of plugs, flats (sod strips) and hydroseed planting techniques on minimizing erosion and improving water quality.
- Determine the effects of compost soil amendment on native vegetative cover, species composition, and weedy annual species suppression.

EXPERIMENTAL DESIGN

Treatments were applied to erosion test boxes to compare flats, plugs, hydroseed jute, and compost applications by measuring the effect of each on water quality and vegetation. The boxes were subjected to natural and simulated rainfall.

A total of 32 erosion test boxes (Figure 1), each measuring 2.0 m x 0.6 m x 0.3 m, were filled with clay loam soil typical of fill material used on construction sites. The soil was compacted to 90% to emulate construction practices. Supports were used to position the boxes at a 2H:1V slope throughout the experiment.

Each box had a randomly assigned position under the box transport system. Vinyl gutters were used to collect runoff from the base of each box and convey runoff into a 7.5 L plastic container. A rectangular piece of synthetic pond liner was cut and riveted to the vinyl gutter to prevent rainfall from directly entering the collection system.

Erosion control treatments included jute netting on combinations of compost and hydromulch with or without seed (Table 1).

Figure 1. Box setup.

Planting treatments included a hydroseed mix applied in combination with plugs or flats of *Bromus carinatus* (California Brome) and *Achillea millefolium* (Common Yarrow) applied on the top and toe or toe only of the slopes (Table 2). The flats and plugs were composed of 50% of each species (Figure 2). Twenty plugs were installed in an area equal to the size of the flats, which measured 0.25 m x 0.5 m or 0.125 m^2 (1.35 ft^2). The erosion test boxes were placed in a random order prior to hydroseeding. The hydroseeded mix included all native plants (Table 3).

Table 1. Erosion Control Teatments.

EC1	Jute w/seed under 2" compost
EC2	Jute w/seed on top of 2" compost
EC3	Jute w/seed on top (no compost)
EC4	Jute w no seed (no compost)
EC5	Seed only (no jute)

Table 2. Seeding/Planting Treatments.

S1	Hydroseed alone
S2	Hydroseed; plugs on toe
S3	Hydroseed; plugs on top and toe
S4	Hydroseed; flats on toe
S5	Hydroseed; flats on top and toe

Table 3. Hydroseed mix.

50%	*Bromus carinatus* (California Brome)
25%	*Festuca microstachys* (Small Fescue)
20%	*Achillea millefolium* (Common Yarrow)
5%	*Lupinus succulentus* (Arroyo Lupine)

Throughout the experiment, natural rainfall was permitted to fall on the boxes. In total, data for six natural storms and one simulated storm were collected (Table 4). The simulated storm was 3.81 cm (1.5 in) of rain over 1.5 hours, equivalent to a 50-year storm.

Figure 2. Flats and plugs on the toe.

Table 4. Applied Storms

Date	Duration	Rainfall	
		cm	in
12/21/03	12/19–12/21/03	5.08	2.00
12/30/03	12/27–12/29/03	3.56	1.40
02/14/03	02/11–02/13/03	5.08	2.00
02/26/03	02/24–02/25/03	1.58	0.62
02/28/03	02/27/03	1.48	0.57
03/04/03	03/03/03	1.07	0.42
05/13/03	1.5 hr Simulation	3.81	1.50

Natural rainfall was measured and recorded by a weather station and backup rain gauges onsite. Additional data were available from a California Irrigation Management Information System (CIMIS) station and a National Oceanic Atmospheric Administration (NOAA, 2003) station on campus.

For simulation purposes, two Norton Ladder variable sweep rainfall simulators were used (Figure 3). The industrial spray nozzles were pressurized to 41 kPa (6 psi), and produced drop sizes averaging a 2.25 mm (0.09 in) diameter. The drop size corresponded to the average drop size of erosive storms in the Midwest region of the United States. Drop size along the Pacific Coast is frequently smaller, but actual measurement data and analysis have not been published.

The nozzles oscillated side-to-side by a cam driven by a small motor. The intensity of simulated rainfall was determined by the number of times the nozzles of the boom swept past the box opening. The

Figure 3. Weather station and rainfall simulators.

frequency and duration of oscillations were altered during each simulation to mimic the theoretical hydrograph of a storm. The simulators were tested before simulations and yielded 95% uniformity. The simulators returned unused rain to the water supply.

Runoff was analyzed for sediment load, pH, and salt concentration. Total solids were analyzed using a procedure that combined methods described by ASTM D3977-97 (ASTM, 2002) and EPA Method 160.2 (EPA, 2001). After collection of each weighed runoff sample, samples received 10–20 ml 1M $AlCl_3$, a common water treatment flocculant. Any remaining sediment on the walls or bottom of the storage container was rinsed into an evaporating dish to be oven dried. The container with sediment was oven dried at 115° C for 24–48 hours and then weighed.

The total water runoff was calculated by subtracting the sediment and container weight from the original total collection weight. The total sediment included the evaporated sediment weight. Sediment concentration (mg/L) was calculated from the total runoff and total sediment values. Salt concentration (electrical conductivity) and pH were analyzed using a pH/EC/TDS/temperature meter built by Hanna Instruments, Inc., for each collection following natural and simulated storm events.

To analyze the effects of planting technique, jute netting, and compost application on vegetation establishment, plant cover was observed directly prior to simulations. Aerial plant cover was the most logical variable to study due to the ability for plant parts to intercept a raindrop before it strikes the soil surface. Government agencies use aerial cover as a standard to determine adequate soil surface protection and compliance with environmental regulations.

Point intercept is the oldest, most objective, and most repeatable procedure for measuring plant cover. For this method, the observer projects a small point from above onto vegetation and soil surfaces (BLM, 1996). Each contact is termed a “hit” for each category of plant species, soil surface litter, rock, or bare soil.

For this experiment, a modified point-transect method was used. A 600 mm length of 20 mm square stock (wood) was notched along the length of each angled face at 25 mm intervals. Along each face 10 positions were selected using random number tables to produce four different point position arrays. The ends of the stock were fixed to the position and allowed to rotate so that the bar was held parallel, approximately 25 mm above the soil surface.

Each soil test box was divided into an upper and a lower half to assess differences in plant cover between the two halves due to gravitational water flow and water retention at the toe of the box. Positions were marked every decimeter along the rails of each box and were selected using computer-generated random number tables to establish unique positions for each box. Positions selected for the upper half were used for the lower half of the same box. Randomly generated numbers were also used to establish sample points along each transect, yielding 100 observations per box. Plant identifications were made based on the observer’s knowledge of the flora. One person observed the vegetation throughout the duration of the study to keep the sampling consistent.

Vegetative cover was analyzed using baseline-category logistic regression (also called polychotomus or nominal logistic regression).

Percent cover was measured in each box-half by determining the presence and type of cover for each of 50 points. If the presence or absence of desirable or undesirable plant matter is considered at each sampled location as the response variable of interest, then this is related to the experimental factors (Montogomery, 1991). Logistic regression is a method by which the presence of plant matter at any point in the box can be modeled as a function of erosion control treatment, vegetation treatment, and other factors.

Water runoff, sediment load in the runoff, and sediment concentration in the runoff were analyzed (after a normalization transformation, if needed) using analysis of variance (ANOVA). Tukey post-hoc multiple comparisons were used to identify differences between individual treatments.

To analyze data trends, runoff and sediment yield measurements were totaled and averaged for boxes with the same planting or erosion control treatment. The boxes were compared to boxes with other treatments and charts were generated to show differences. Totals were analyzed for the 50-year simulated event.

RESULTS

Water Quality

Planting treatments had varied effects on overall water quality. For all storms, natural and simulated, flats planted on the toe yielded significantly less total runoff than hydroseeding alone or plugs on the toe only. There was no significant difference between the other planting treatments for runoff. There were no significant differences between total sediment load yield for planting treatments ($p = 0.639$). Planting treatment showed no significant effect on sediment concentration ($p = 0.477$).

For the 50-year simulated storm event, trends show that flats or hydroseeding alone yielded less than 20% of the runoff produced by bare ground (Figure 4). Flats on the top and toe yielded 82% less runoff than plugs on the top and toe.

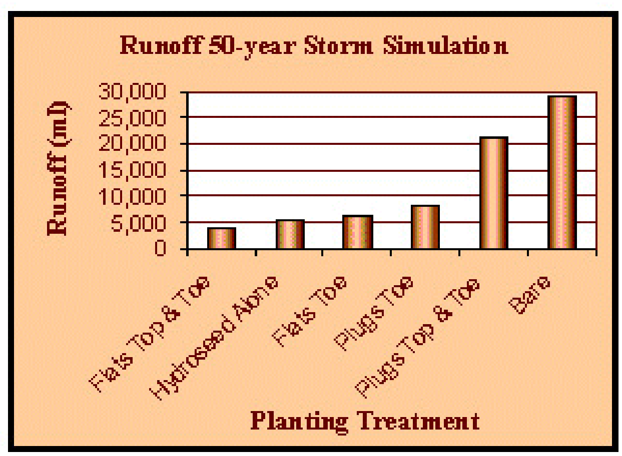

Figure 4. Runoff 50-year storm simulation.

Trends also indicate that flats on the top and toe, or the toe only, removed up to 99% of the amount of sediment produced by bare ground during a 50-year storm event (Figure 5). Furthermore, flats removed up to 85% of the sediment produced by boxes treated with hydroseeding alone. Overall, planting treatments increased infiltration of rainfall.

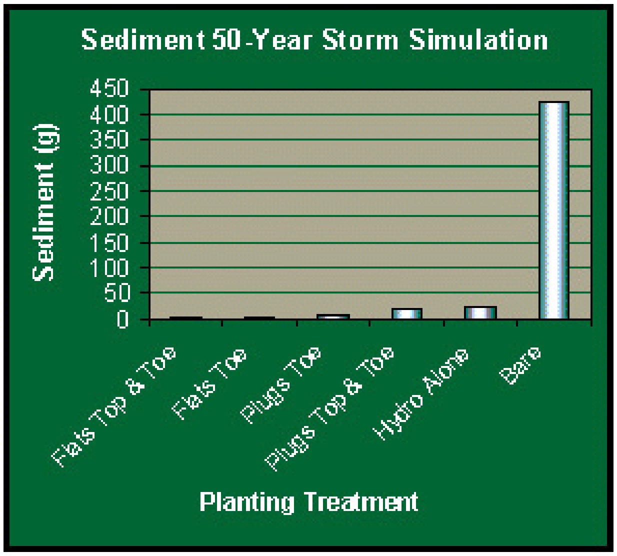

Figure 5. Sediment load 50-year storm simulation.

Erosion control treatments affected runoff ($p < 0.001$), sediment load ($p < 0.001$), and sediment concentration ($p = 0.042$). Jute with seed on top of 5.08 cm (2 in) of compost yielded significantly less total runoff compared to all other erosion control treatments (Figure 6). Jute with compost and/or seed removed

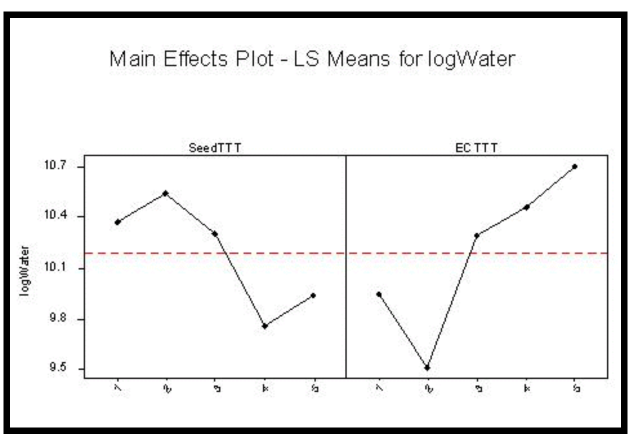

Figure 6. Runoff main effects plot—LS means for logWater.

significantly more sediment from runoff than no seed and/or no compost. No individual treatments were identified as significantly different.

EC treatment also affected pH levels and salt concentrations for all storms (Figure 7). Higher pH and salt concentrations were detected in the runoff from boxes treated with compost, but the levels were not harmful to plant growth (Smith, 2002).

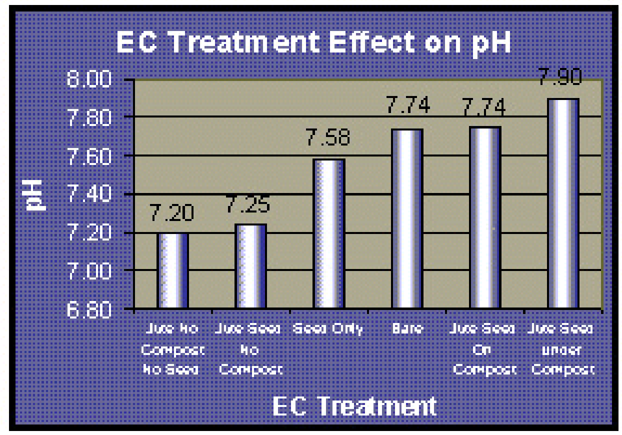

Figure 7. EC treatment effect on pH levels.

Vegetation

Overstory Cover

The upper portion of the box produced significantly lower cover of both desirable ($p < 0.001$) and undesirable plants ($p < 0.001$) compared to the lower portion of the box. On average, the use of jute significantly decreased desirable cover ($p < 0.001$). Jute had no noticeable effect on undesirable cover ($p = 0.535$); however the use of jute limited the cover in the upper portion of the box and increased the cover in the lower portion of the box ($p = 0.025$).

The use of compost had no noticeable effect on desirable cover ($p = 0.859$), but reduced undesirable cover ($p < 0.001$). For boxes with hydroseed beneath compost, the desirable cover did not significantly change ($p = 0.060$), but undesirable cover increased ($p < 0.001$). The effect of compost on desirable cover depended on the box division ($p < 0.001$). The upper portion of the box with compost decreased desirable cover. Similarly, the effect of compost on the undesirable cover depended on box-division (p =

0.002) and the upper portion of the box with compost decreased undesirable plant cover.

On average, hydroseeding, with other treatments, increased desirable cover ($p < 0.001$) and decreased undesirable cover ($p < 0.001$). In the upper portion of the box, hydroseeding had a stronger effect on desirable cover than in the lower portion of the box ($p = 0.048$). Similarly, hydroseeding had a stronger effect on the undesirable species in the upper portion of the box than in the lower portion ($p < 0.001$).

The use of flats compared to plugs lowered the desirable cover ($p < 0.001$) but did not appear to affect the undesirable species ($p = 0.428$). Planting the top and toe increased both the undesirable ($p = 0.002$) and desirable cover ($p = 0.036$). On average, hydroseeding alone did not appear to affect either the desirable ($p = 0.374$) or undesirable cover ($p = 0.724$). However, hydroseeding alone did increase the desirable cover in the upper portion of the box ($p = 0.048$). Overall overstory cover increased over time; however, the increase appeared to be during the first month. Table 5 serves as a guide to the statistical results for this experiment. It should be read horizontally to determine the effect of applying a particular treatment to bare soil. Individual sites should be evaluated prior to applications.

Understory Cover

The upper portion of the box had significantly lower desirable cover ($p < 0.001$) but the undesirable cover was not significantly different ($p = 0.395$). Jute appeared to have no effect on desirable understory cover ($p = 0.298$) but reduced undesirable cover ($p = 0.005$). However, in the upper portion of the box, jute yielded lower desirable cover ($p = 0.007$).

On average, compost reduced desirable understory cover ($p = 0.041$) but had no effect on undesirable cover ($p = 0.370$). Compost had a greater effect on desirable species in the lower portion of the box than in the upper portion of the box ($p < 0.001$). Seeding under the compost significantly decreased the desirable cover ($p < 0.001$) but did not significantly increase undesirable cover ($p = 0.248$). However, in the upper portion of the box, seeding under the compost produced more desirable cover than in the lower portion of the box (p <.0.001).

Table 5. Summary of Treatment Effects on Overstory Cover.

Overstory Cover	Desirable Cover		Undesirable Cover	
Treatment Type	Upper Slope	Lower Slope	Upper Slope	Lower Slope
EC Jute	↓	↓	↓	↑
EC Compost	↓	↔	↓↓	↓
EC Seed Under Compost	↔	↔	↑	↑
EC Hydroseeding	↑↑	↑	↓↓	↓
S Hydroseeding Alone	↑	↔	↔	↔
S Flats	↑	↑	↑	↑
S Plugs	↑	↑	↑	↑
Lower vs. Upper Box	↓	↑	↓	↑
Time	↑	↑	↑	↑

↑: Increases Cover ↓: Decreases Cover ↓↓ **or** ↑↑: Stronger Effect ↔: No Noticeable Effect

Hydroseeding as an erosion control treatment significantly increased desirable cover ($p < 0.001$) but did not significantly affect undesirable cover ($p = 0.293$).

Flats and plugs on the top and toe increased both the desirable ($p < 0.001$) and undesirable cover ($p = 0.001$). Where flats were planted, as opposed to plugs, desirable cover increased ($p < 0.001$). Hydroseeding alone produced less desirable cover in the lower portion of the box ($p < 0.001$) as compared to flats and plugs but did not significantly affect undesirable cover ($p = 0.080$). Overall understory cover increased over time; however, the increase appeared to be during the first month. Table 6 serves as a guide to the statistical results for this experiment. It should be read horizontally to determine the effect of applying a particular treatment to bare soil. Individual sites should be evaluated prior to applications.

DISCUSSION

All treatments improved water quality when compared to bare ground (Figure 8). Jute combined with compost performed well as an erosion control treatment, producing little sediment and runoff. However, jute slightly inhibited cover, whether desirable or undesirable. Compost did suppress understory weeds but did not promote the perennial natives, and allowed weeds to compete when the natives were seeded beneath the compost. This suggests that compost does not provide an advantage to the natives seeded in this experiment, and 5.08 cm (2 in) of material can actually inhibit germination of these species.

Additionally, pH was affected by treatment types and combinations of treatments. Jute alone seemed to decrease pH, while compost increased pH. Changes could be important depending on water quality standards of receiving water bodies.

The installation of the native flats and plugs decreased sediment load and runoff yield, and improved perennial native cover. Flats consistently performed the best, whether planted on the top and toe or toe only, suggesting that vigorous vegetative protection on the top and toe of a slope is crucial. Both native and undesirable cover established poorly on the upper portion of the boxes, which should be taken into consideration when establishing vegetation on slopes and planning irrigation regimes. When installed on the top and toe or toe only, plugs performed well and may be beneficial if access to sod is limited for a particular construction site.

Table 6. Summary of Treatment Effects on Understory Cover.

Understory Cover	Desirable Cover		Undesirable Cover	
Treatment Type	Upper Slope	Lower Slope	Upper Slope	Lower Slope
EC Jute	↔	↓	↓	↓
EC Compost	↓↓	↓	↔	↔
EC Seed Under Compost	↓	↓↓	↔	↔
EC Hydroseeding	↑	↑	↔	↔
S Hydroseeding Alone	↔	↓	↔	↔
S Flats	↑↑	↑↑	↑	↑
S Plugs	↑	↑	↑	↑
Upper vs. Lower Box	↓	↑	↔	↔
Time	↑	↑	↑	↑

↑: Increases Cover ↓ : Decreases Cover ↓↓ **or** ↑↑: Strong Effect ↔: No Noticeable Effect

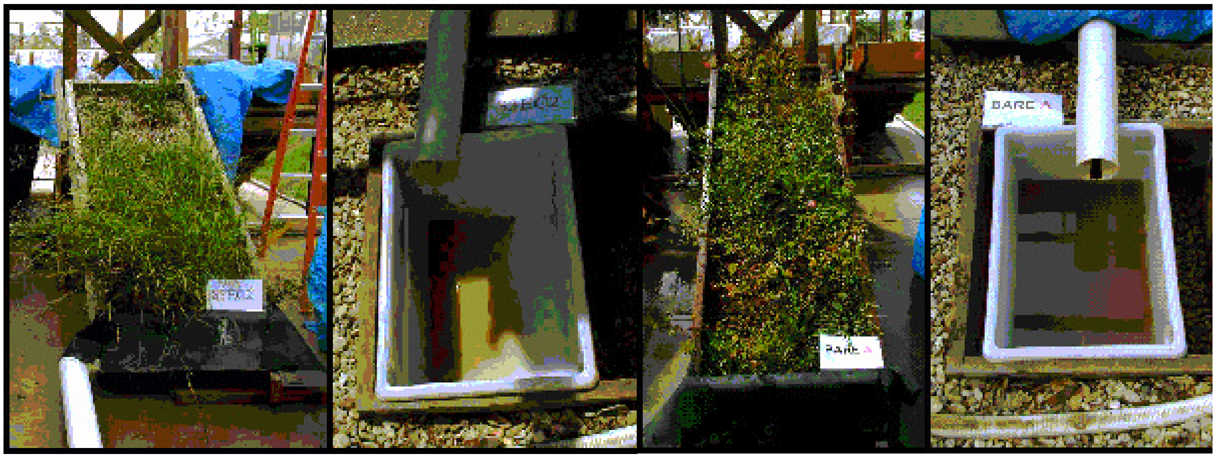

Figure 8. Plugs and jute with seed on compost vs. bare ground or no treatment with weedy annual vegetation.

Hydroseeding increased overstory and understory native cover when combined with flats and plugs. Hydroseeding alone decreased native cover. This indicates that the pre-started vegetation, such as flats and plugs, offers increased infiltration and soil stability that enhance seed establishment early plant growth.

CONCLUSION

Flats on the top and toe, when combined with jute netting and hydroseeding applied mid-slope, should perform the best for encouraging native plant establishment and minimizing soil erosion.

Soil conditions at all sites should be evaluated prior to plant installation. Specific species should be researched thoroughly to determine particular water and nutrient requirements. Natives of the particular region should be used, as these species are acclimated to the climate and conditions of the area.

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