AIIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910

301/587-8202

Centimeter

Inches

MANUFACTURED TO AIIM STANDARDS
BY APPLIED IMAGE, INC.

1 of 1

Conf-940292--1

WHC-SA-1968-FP

Improving Revegetation Success-Evaluation of Several Soil Treatments

Prepared for the U.S. Department of Energy
Office of Environmental Restoration and
Waste Management

Westinghouse
Hanford Company Richland, Washington

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

Copyright License By acceptance of this article, the publisher and/or recipient acknowledges the U.S. Government's right to retain a nonexclusive, royalty-free license in and to any copyright covering this paper.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Approved for Public Release

WHC-SA-1968-FP

Improving Revegetation Success-Evaluation of Several Soil Treatments

W. M. Hayward
M. R. Sachschewsky
S. J. Kemp

Date Published
September 1993

To Be Presented at
The IECA's 25th Annual Conference and
Trade Exposition
Reno, Nevada
February 15-18, 1994

Prepared for the U.S. Department of Energy
Office of Environmental Restoration and
Waste Management

Westinghouse Hanford Company P.O. Box 1970 Richland, Washington 99352

Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

Copyright License By acceptance of this article, the publisher and/or recipient acknowledges the U.S. Government's right to retain a nonexclusive, royalty-free license in and to any copyright covering this paper.

Approved for Public Release

LEGAL DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced from the best available copy.

Printed in the United States of America

DISCLM-2.CHP (1-91)

IMPROVING REVEGETATION SUCCESS - EVALUATION OF SEVERAL SOIL TREATMENTS

W. M. Hayward
M. R. Sackschewsky
C. J. Kemp

ABSTRACT

The current Hanford practice for stabilizing contaminated soil sites and retired burial grounds involves placing 0.6 meter or more (2 or more feet) of clean soil over the surface, followed by revegetation. This procedure has resulted in the establishment of a viable plant cover at a number of locations. In other cases, however, these efforts have failed to establish healthy shallow-rooted grass coverage.

The establishment of a viable plant community is inherently difficult on the Hanford Site for a variety of reasons, including inadequate and sporadic natural precipitation; windy conditions that produce large erosive forces; soils low in nutrients and organic matter; invasion of disturbed sites by aggressive, weedy annuals; and limited supplies of quality topsoil.

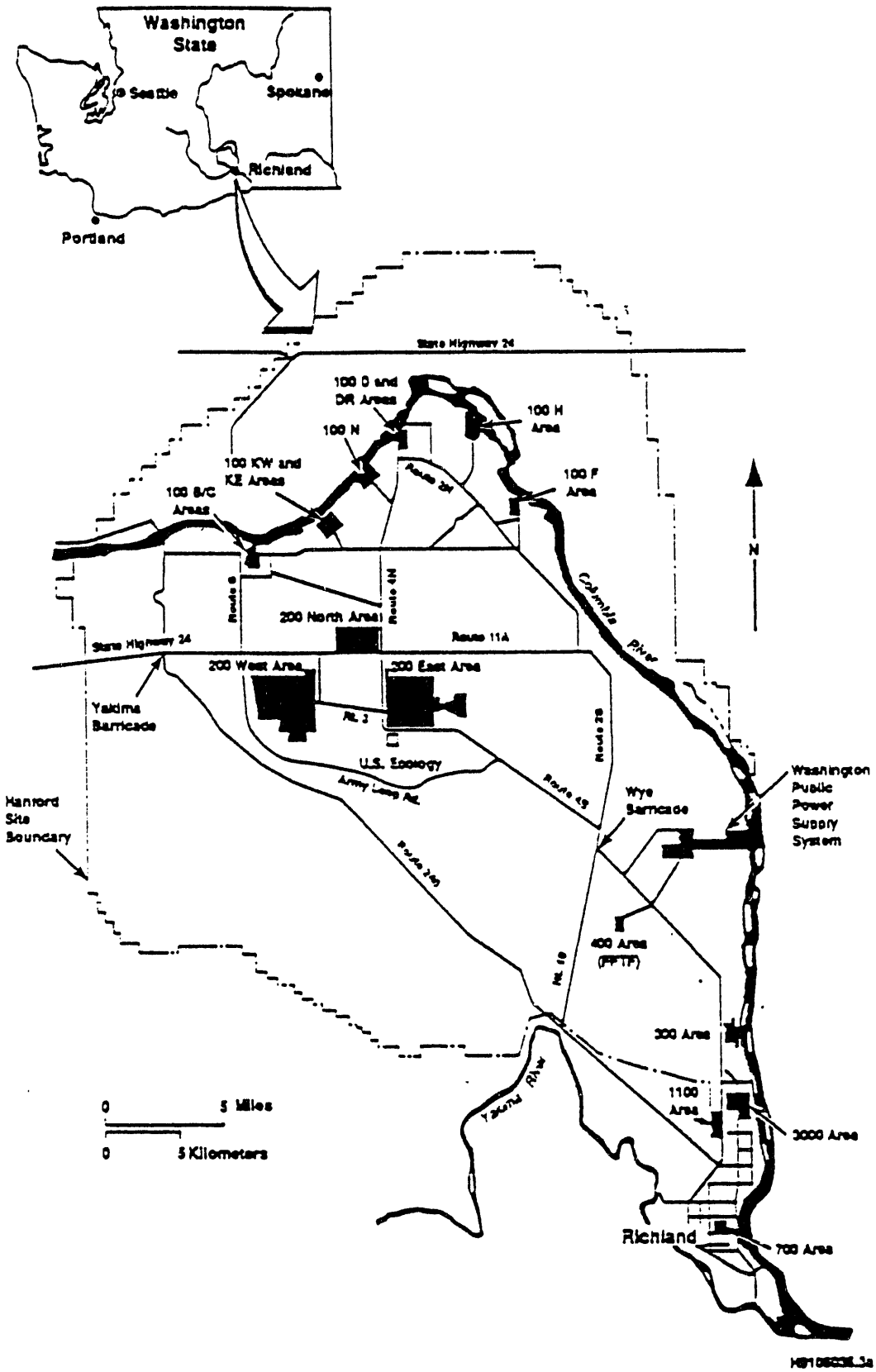
This report describes the results of work designed to address three environmental issues (soil moisture, erosion, and soil nutrients). Compost and soil sealants were evaluated in various combinations with the expectation of developing revegetation procedures with a higher probability of success.

INTRODUCTION

The Hanford Site, operated by the U.S. Department of Energy (DOE), occupies about 1,450 km^2 (560 mi^2) of the southeastern part of the state of Washington north of the confluence of the Yakima and Columbia Rivers (Figure 1). The Hanford Site was established in 1943 to produce plutonium for nuclear weapons, using production reactors and chemical processing plants. That mission has now ended and the Site is in the early stages of a several decade cleanup program to address the legacy of radioactive and chemical wastes that remain in storage or have been placed in the soil column.

One important element of this cleanup is the stabilization and maintenance of the individual soil waste sites and burial grounds until the regulatory and technical requirements for final remediation are executed. Several techniques are currently in use to stabilize the sites. These include (1) stabilization with 0.6 m (2 ft) of clean soil followed by revegetation (the primary method), (2) stabilization with soil or rock followed by sterilization with herbicide, (3) stabilization by application of shotcrete with or without a chemical biobarrier, and others. Although no single method can be applied universally at all sites, adding clean soil and revegetating has been the preferred method for the majority of the sites and has been

Figure 1. Location of the Hanford Site.



successfully used on over 404 hectares (1000 acres). The main difficulty with this method is the establishment of a viable plant community. Unsuccessful revegetation results in increased total costs of stabilization because of the repeat efforts to establish the vegetation. In addition, an unsuccessful stabilization effort increases the potential for future contamination spread from the affected area.

The establishment of a viable plant community is inherently difficult on the Hanford Site for a variety of reasons. There is inadequate and sporadic natural precipitation (15.9 cm/yr [6.25 in./yr]); windy conditions at various times during the year produce large erosive forces; soils are low in nutrients and organic matter; aggressive, weedy annuals invade disturbed sites; and supplies of quality topsoil are limited.

Previous work (Cox 1981) that led to the revegetation methods currently used has shown that Russian thistle (the primary invasive weed) can be adequately controlled by the correct use of broadleaf herbicides if the materials are applied properly and with appropriate frequency and timing. The limited supply of available quality topsoil is problematic for Hanford Site interim stabilization activities. The work described in this report is designed to address three environmental issues (soil moisture, erosion, and soil nutrients). A composted sludge product and two soil sealants in various combinations were evaluated with the objective of developing revegetation and stabilization procedures that will have a higher probability of success than current practices.

DESCRIPTION OF TESTS

The tests described in this report are designed to investigate the effects of soil sealants and composted sewage sludge. Composted sewage sludge was applied to test its effects on the amounts of plant-available nutrients, the water-holding capacity of the soil, the amount of organic matter in the soil matrix, and erosion protection of the seedlings. Light applications of soil sealants were used to test (1) their ability to decrease the rate of evapotranspiration and (2) their usefulness in erosion protection.The composted sewage sludge was chosen over noncomposted because it is a nonregulated product. The sealants were also selected on the basis of their being "nonhazardous." Theoretically, if both compost and soil sealants are provided, the combination of these effects should provide a greater soil moisture and nutrient rich environment, as well as enhanced erosion protection, for plant growth and development compared to untreated soil conditions. Over these soil treatments two different mixtures of seed were applied--a "standard mix" of Siberian wheatgrass *(Agropyron sibericum)* and thickspike wheatgrass *(Agropyron dasytachyum)*, and a "native mix" of thickspike wheatgrass, Indian ricegrass (*Oryzopsis hymenoides*), sheep fescue (*Festuca ovina*), bottlebrush squirreltail (*Sitanion hystrix*), needle-and-thread (*Stipa comata*), and Sandberg's bluegrass (*Poa sandbergii*).

Periodic measurements in fiscal year (FY) 1992 and 1993 included plant coverage, monthly soil moisture monitoring using neutron activation, and soil nutrient status. In 1992 only, germination counts were taken, and in 1993, total plant aboveground biomass was measured.

Test Plot Construction

Test plots were set up during July and August 1991. The test plots are located in the 200 East Area, in the central portion of the Hanford Site.

The area chosen for these test plots was an area stripped of topsoil during the spring 1991 for the remediation of a nearby contaminated site. The area was surveyed, and the plots were staked out in June. Following the plot survey, 230 m^3 (300 yd^3) of compost was delivered and spread to a depth of 11.4 cm (4.5 inches) by an offsite vendor on one-half of the strips. Aerospray-70A, a trademark of American Cyanamid Company, was applied with a hand-operated airless sprayer at a rate of 4.1 L/m^2 (0.1 gal/ft^2) in a 1:1 product-to-water mix. Enduraseal was also applied by an offsite vendor. The application rate could not be accurately determined but is calculated to also be approximately 4.1 L/m^2 (0.1 gal/ft^2). The final surface treatment layout is provided in Figure 2.

Neutron probe access ports were installed in August 1991. Each is a thick-wall aluminum tube 1 m (3 ft) long buried in a hole dug with a backhoe. The surface around the tube was then reconstructed by hand in an attempt to re-establish the compost and/or soil sealant surface. A total of 36 access ports were installed in plots 2, 3, and 6.

Seed was drilled in September 1991. Ammonium phosphate fertilizer was co-applied with the seed at a rate of 140 kg/hectare (125 lb/acre), equivalent to 22.4 kg nitrogen/hectare (20 lb/acre).

Fertility Testing Methods

Soil fertility samples were taken three times during FY 1992 (November, May, and August) and once during FY 1993 (May). These sampling periods correspond to the following times: after early winter moisture had produced visible plant germination, in late spring following the majority of first year growth, late summer following the period of annual grass die-off, and late spring following the majority of the two year period of growth and germination. The purpose of these samples was to quantify and characterize nutrient status during the study period. Samples were taken from each of the compost/soil sealant test treatments. The soil samples were analyzed with a small, field portable test kit. Even with some accuracy limitations, the data collected with the test kit indicated some fertility differences corresponding to the treatments used on the plots. The nitrate and pH data from each of the analyses are provided in Table 1.

First Year Fertility Test Results

In FY 1992, plots with compost-amended soil had a lower soil pH than plots with no compost. Many micro and trace nutrients become more readily available to plants with a reduction in soil pH. On all plots, micronutrient values were low, being limited by high or neutral soil pH and low cation exchange capacity.

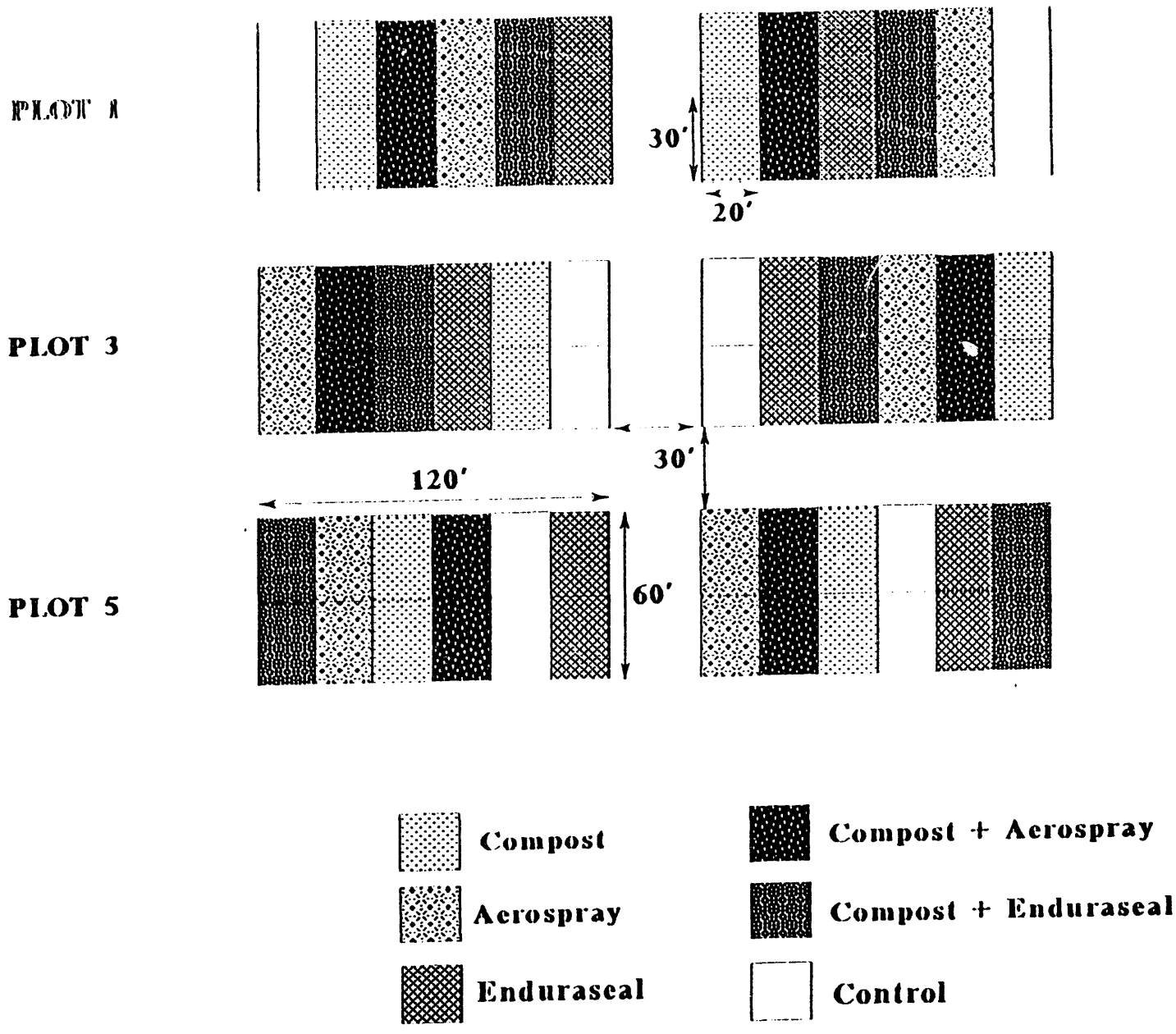


Figure 2. Layout of Test Plots.

Table 1. Nitrate and pH Soil Test Data.

TEST ELEMENT DATE	CONTROL	CONTROL+ AEROSPRAY	CONTROL+ ENDURASEAL	COMPOST	COMPOST+ AEROSPRAY	COMPOST+ ENDURASEAL
NITRATE kg/hectare						
11-91	11.2	22.4	11.2	168	112	168
5-92	<11.2	<11.2	<11.2	67.2	67.2	67.2
8-92	<11.2	<11.2	<11.2	67.2	67.2	67.2
5-93	<11.2	<11.2	<11.2	<11.2	<11.2	<11.2
pH						
11-91	8.0	8.0	7.8	6.6	6.4	6.6
5-92	8.4	8.4	8.6	6.6	6.6	6.6
8-92	8.2	8.0	8.4	7.0	6.6	6.6
5-93	8.4	8.2	8.2	7.0	6.8	6.8

Compost-amended plots exhibit much higher levels of plant-available nitrogen, in comparison to plots not treated with compost. Phosphorus, potassium, calcium, and iron did not appear to be limiting in any of the treatments. Clearly the compost-amended plots have higher humus content than plots without a compost amendment. No significant soil fertility differences are attributed to Aerospray or Enduraseal. It is highly unlikely that these products provided any nutrients directly to the soil resulting from material compositions. Soil fertility values are correlated to the amount of grass growth on the different plot treatments.

Second Year Fertility Test Results

The soil fertility factors tested in FY 1993 included soil pH, nitrate nitrogen, phosphorus, potassium, humus, ammonia nitrogen, and nitrite nitrogen. All treatments tested showed very high amounts of available phosphorus and potassium, adequate for perennial and annual plant growth. Significantly, all plots with compost or compost plus soil sealants had adequate amounts of ammonia nitrogen but low amounts of nitrite or nitrate nitrogen. Therefore, composted plots do have available nitrogen for nitrification. Nitrification on the composted plots is most likely limited by low soil moisture available for nitrobacteria activity and high carbon-to-nitrogen ratios in the soil organic matter. However, plots without compost exhibited very low amounts of ammonia, nitrite, and nitrate nitrogen. Plots with compost-amended soil all still have lower soil pH in year 2 of the tests than plots with no compost. Many micro and trace nutrients become more readily available to plants as soil pH decreases.

As in the first year, the compost-amended plots have higher humus content than plots without a compost amendment. No significant soil fertility differences are attributed to Aerospray or Enduraseal. Soil fertility values are correlated to the amount of grass growth on the different plot treatments.

Soil Moisture Measurements

Soil moisture measurements were collected monthly on the stabilization test plots in FY 1992 and 1993. Over the two test years the only months in which data were not collected were November 1991 and September 1992. The soil moisture measurement was performed using a neutron source hydroprobe. The hydroprobe was calibrated using standards consisting of two 55-gallon barrels filled with test plot soil placed below surface grade. One of the barrels was filled with air dry surface soil. The other barrel had air dry soil wetted with additional water to near field capacity. The moisture of the wet soil barrel was determined to be 15.36% moisture by weight during the first year of the test and was then recalibrated to 13.2% moisture by weight in the second year of the test. The dry soil barrel was determined to be 1.62% moisture by weight in the first year and 1.4% moisture by weight in the second year of the test.

All treatments were measured monthly from three different whole plots: 2, 3, and 6. During each monthly measurement period a set of standard measurements were gathered from the calibration barrels at both the beginning and end of the measurement period. All of the treatment plots within whole plots 2, 3, and 6 were measured at depths of 90 cm, 75 cm, 60 cm, 45 cm, and 30 cm.

Soil Moisture Results

The patterns of soil moisture content at each depth except 90 cm are provided in Figures 3 through 6. The soil water content at all depths was greatest during the late winter and early spring months of each year. Actual and normal precipitation is shown in Figure 7. During the winter of 1992 the maximum moisture content was between 8% and 10% in the plots with compost and between 6% and 7% in the plots without compost. During the second winter the maximum soil water content was over 9% in all of the plots, except at the two deepest depths. The winter of 1992/1993 was unusual because of the large amount of snow and the length of time it remained on the ground. This explains the lack of differences between the composted and noncomposted plots. During a normal winter (more like 1991/1992) soil moisture is lost by evaporation during the dry periods. In 1992/1993, the snow cover acted as a mulch and prevented the usual evaporative losses. During the summer months, all of the treatment plots dried out to approximately 1% to 3% soil moisture, with the deeper soil layers remaining slightly wetter than the upper soil layers. This drying can be attributed to combined soil evaporation and plant transpiration.

Moisture data were analyzed further for five selected sampling dates: October 1991, February 1992, October 1992, March 1993, and July 1993. These dates were selected to correspond to the driest and wettest periods of the seasonal cycle. These data are presented in Figure 8. The only significant finding in these analyses was that compost-amended plots had significantly

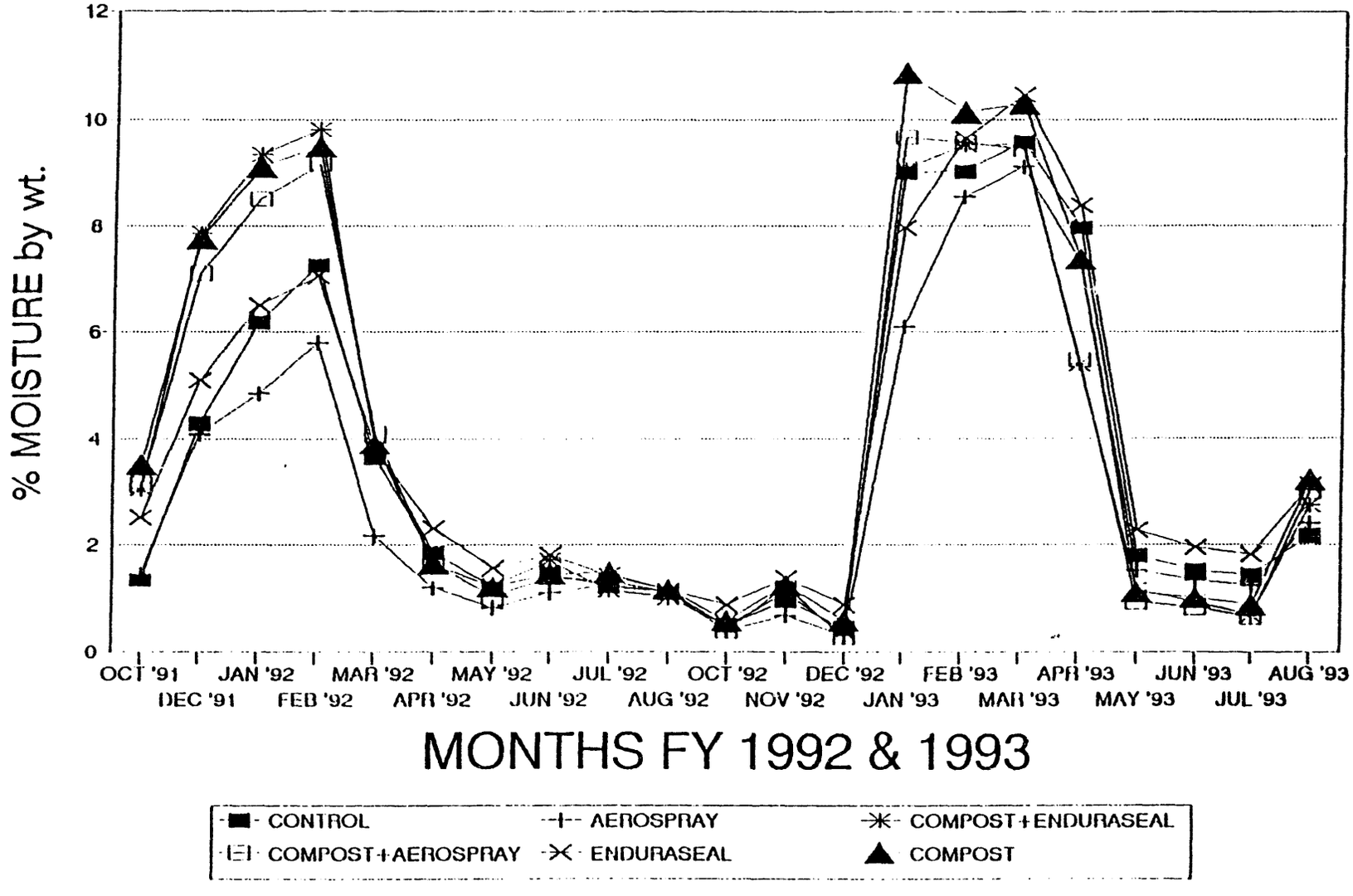


Figure 3. Average Moisture % by Weight - 30 cm Depth.

Figure 4. Average Moisture % by Weight - 45 cm Depth.

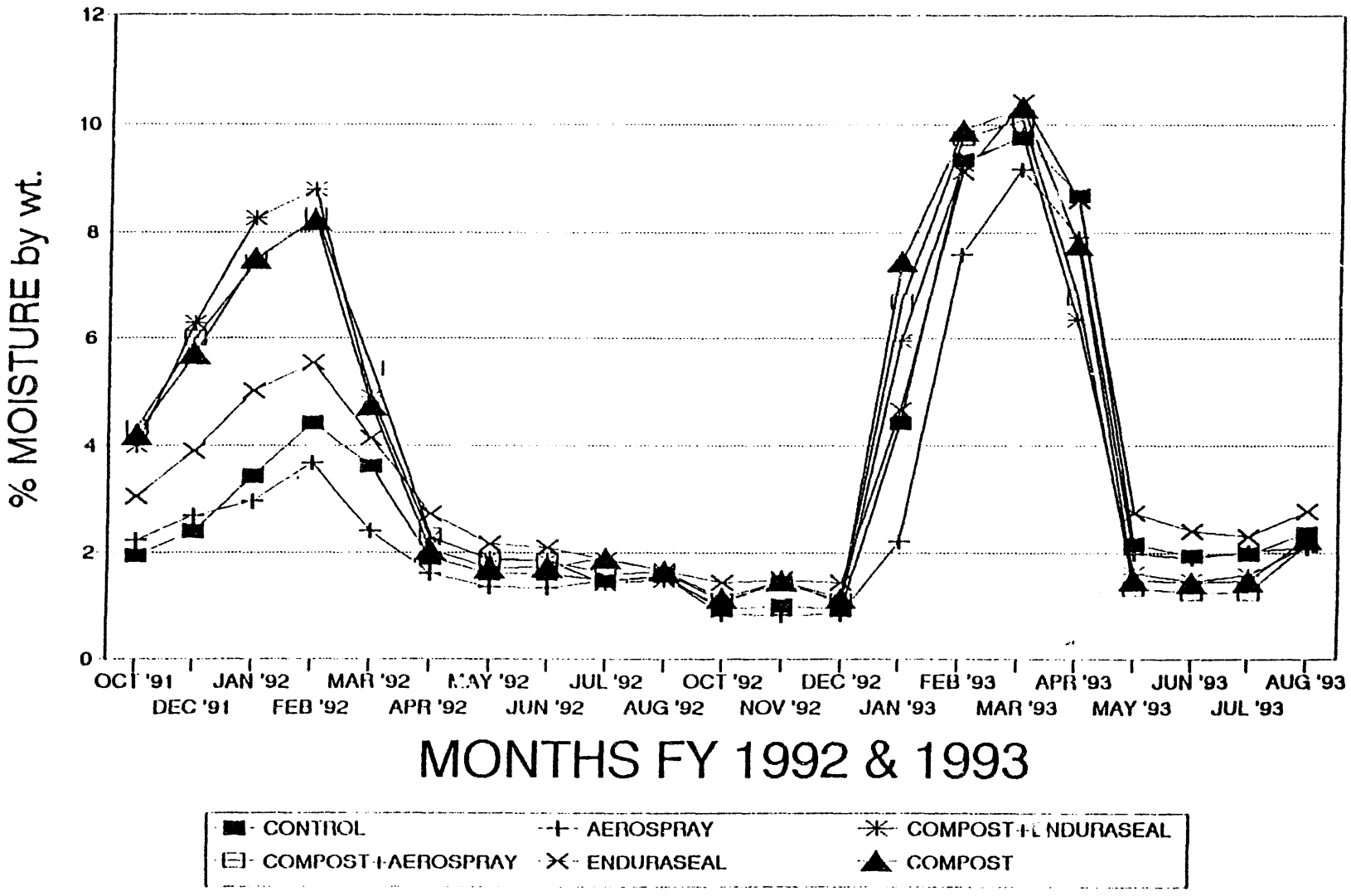
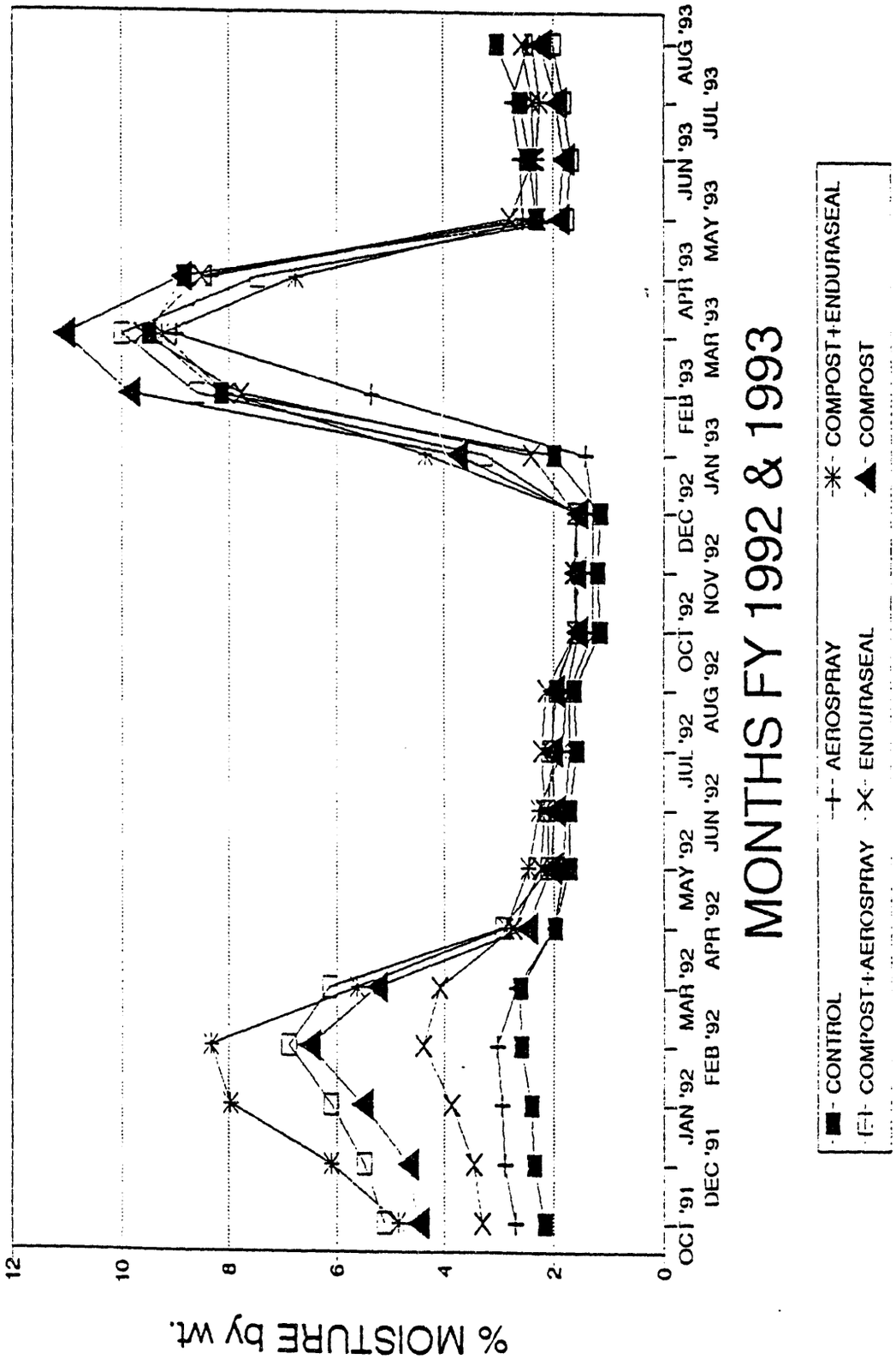


Figure 5. Average Moisture % by Weight - 60 cm Depth.



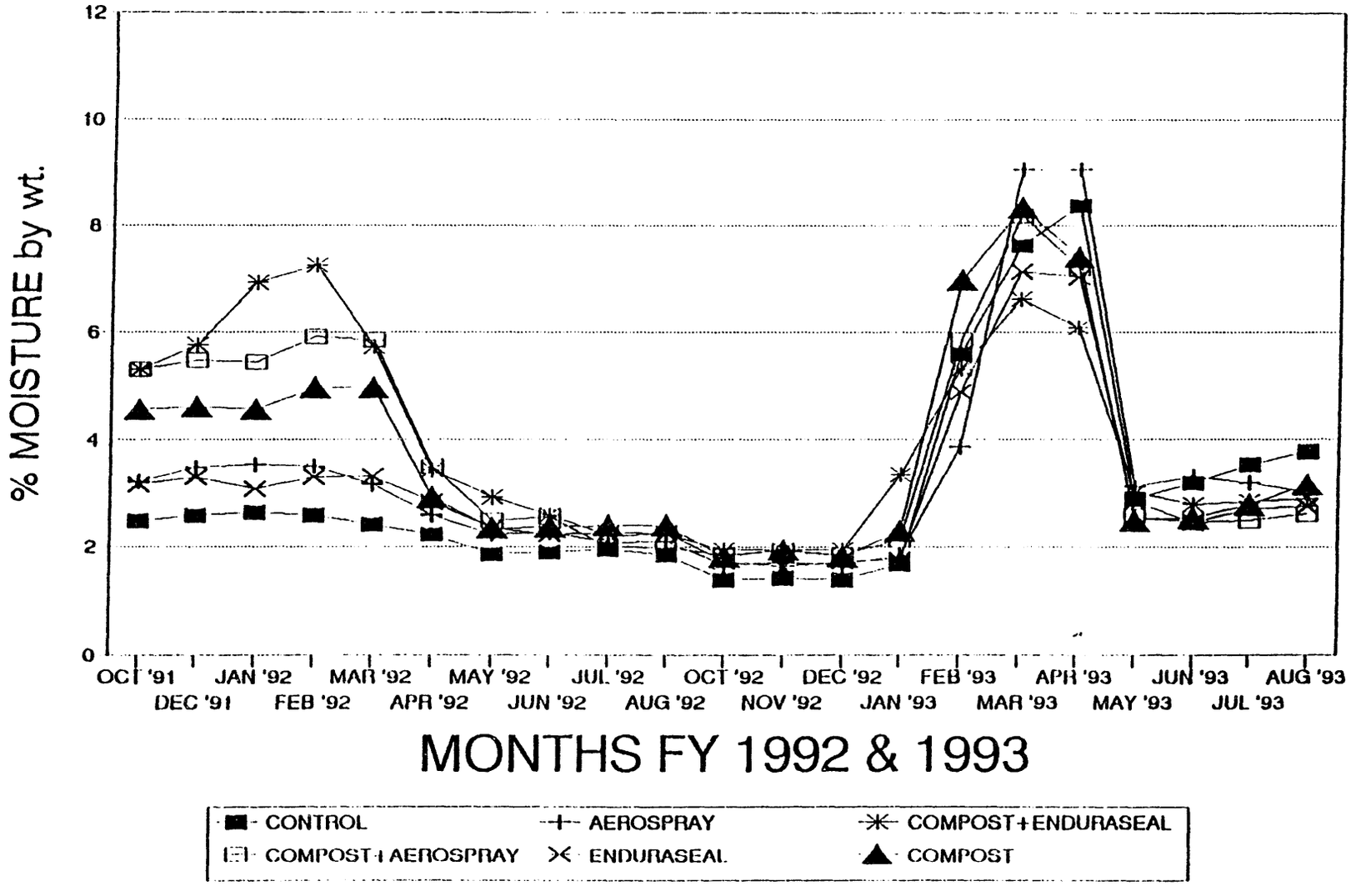


Figure 6. Average Moisture % by Weight - 75 cm Depth.

Figure 7. Hanford Precipitation Totals.

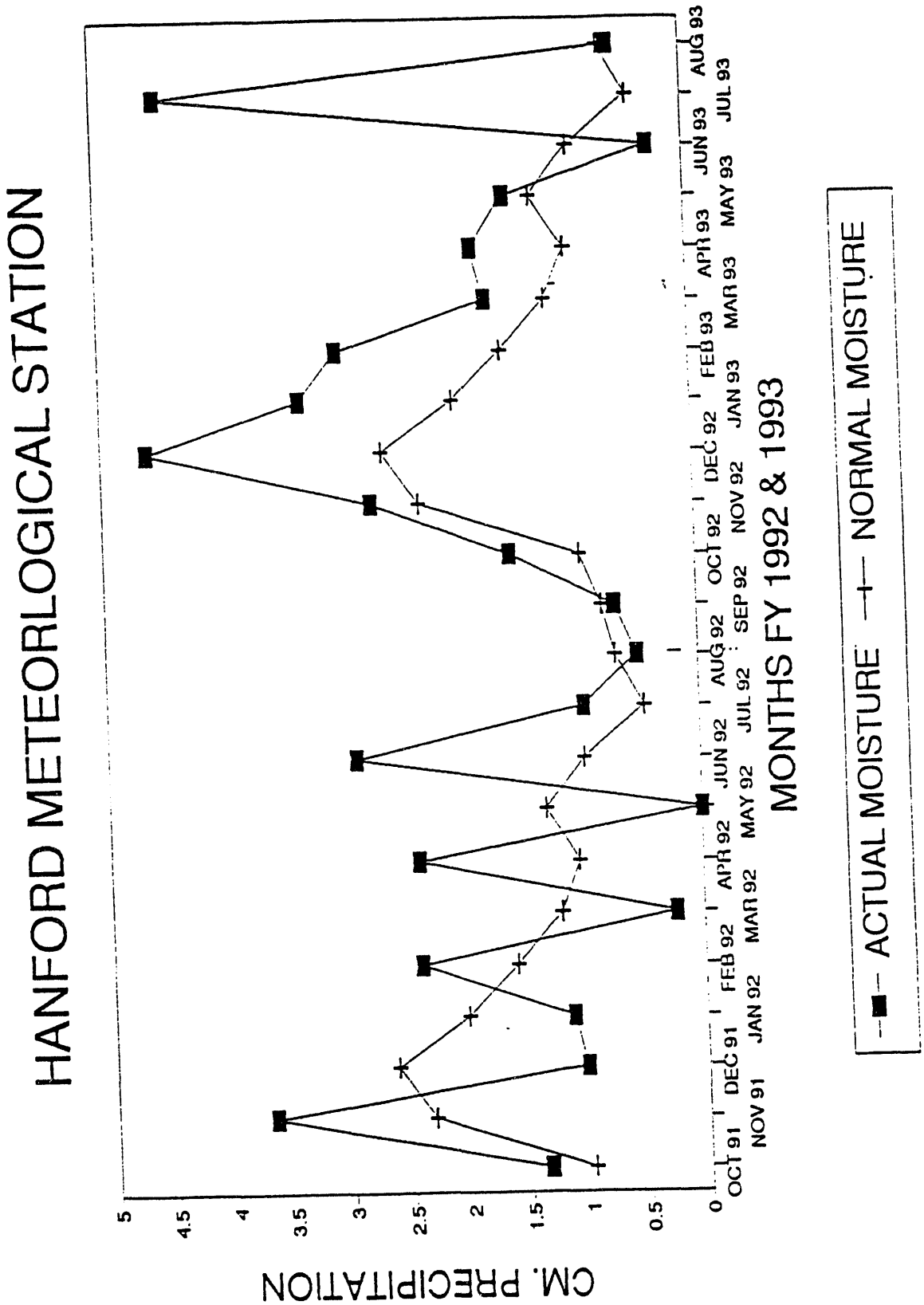
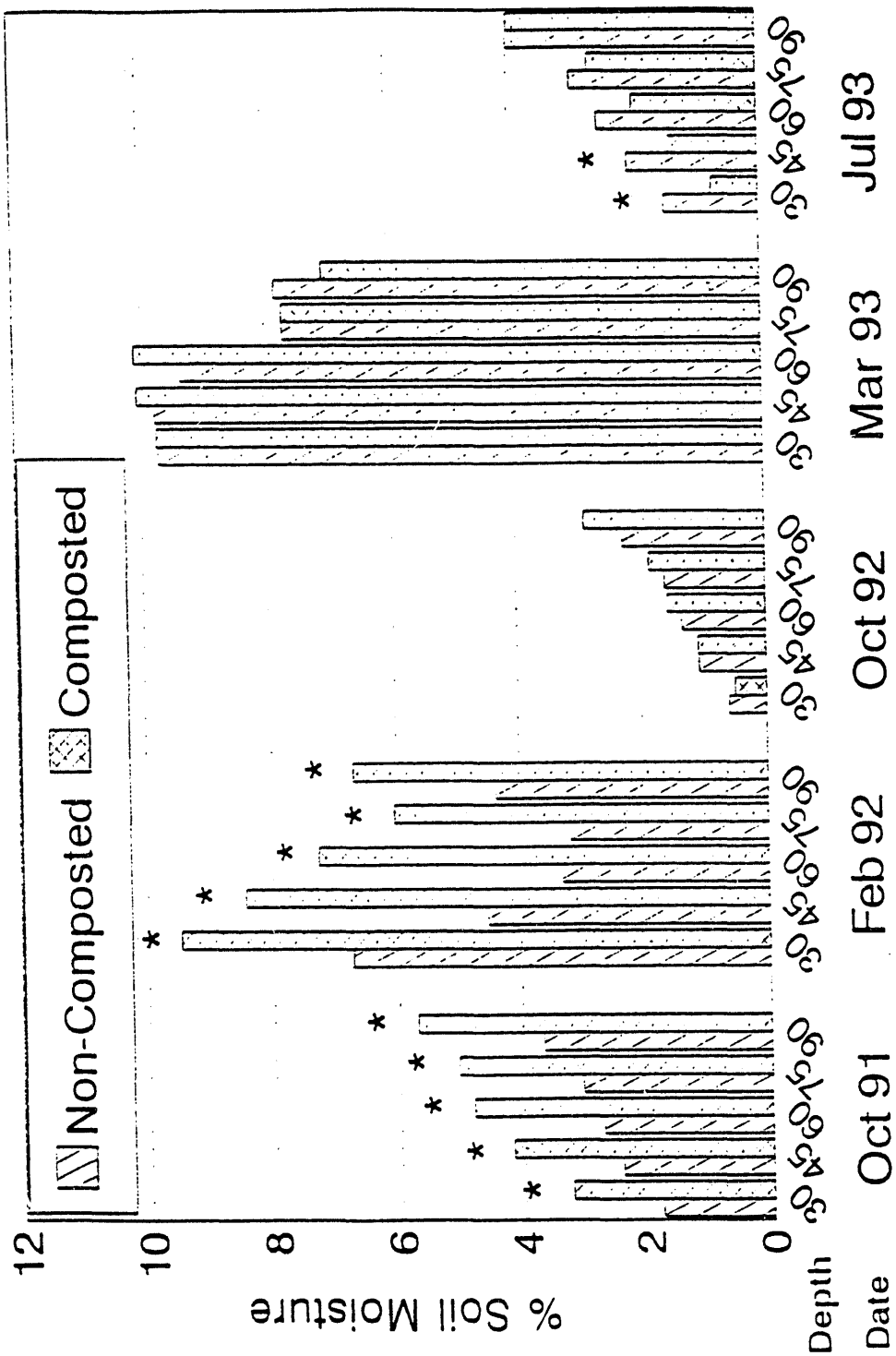


Figure 8. Compost Effects on Soil Moisture Storage.



* indicates that the compost and non-compost values are significantly different for that date and depth.

higher soil moisture at all depths during the October 1991 and February 1992 measurement periods. The differences between the composted and noncomposted plots are not significant on any of the last three sampling dates analyzed except for the 30 cm and 45 cm depths in July 1993. Here the composted plots are actually drier than the noncomposted plots. This can be attributed to the presence of a greater biomass that more aggressively withdraws soil moisture for transpiration compared with the sparser biomass on the noncompost plots, which is unable to use as much of the limited soil moisture.

In general, no significant effects of soil sealant type were found, although the plots with Enduraseal were typically slightly wetter, and those with Aerospray slightly drier than the plots with no soil sealant. The interaction between sealant type and compost was not significant at any soil depth on any of the sampling dates analyzed.

First Year Plant Community Measurements

Measurements of the developing plant community were taken at two points during the 1992 growing season. Seedling density for both perennial and cheatgrass were determined in March 1992, and canopy coverage and species frequency were determined in June. These points correspond to seedling survivorship through the winter and plant development through the spring growth period.

The March seedling density values were determined by counting the number of seedlings within a 500-cm^2 circle. Because different perennial grass species are very difficult to differentiate at this stage, they were grouped into a single category "perennial." Three replicates within each plot/treatment subplot were collected by random placement of the quadrant frame.

In June, the canopy coverage was determined using a point intercept plot frame. Four replicates per subplot were collected by random placement of the plot frame. Data collected included the canopy coverage and frequency of perennial grasses, coverage of cheatgrass, and the coverage of the broadleaf weeds, Russian thistle (*Salsola kali*), tumblemustard (*Sisymbrium altissimum*), and tarweed (*Amsinkia lycopsoides*). For analysis purposes the coverage values for all of the broadleaf weeds were combined. Again, no attempt was made to distinguish the type of perennial species present. The perennial frequency was determined by the percent of the plot frame positions that had at least one perennial plant within the 0.5 m^2 frame. The frequency for cheatgrass was 100% and for weeds it was almost 100%. Canopy coverage is determined by the proportion of predetermined points occupied by a particular species.

First Year Results

There were no significant differences in either the perennial or the cheatgrass density among the different surface treatments. A considerable amount of variation was encountered both among plots and among replicates within plots.

Both the perennial coverage and frequency were significantly higher in the plots with compost than in the plots without compost. The soil sealants themselves did not significantly affect the perennial coverage or frequency (Figures 9 and 10). The perennial canopy coverage was higher in the plots that had both compost and Aerospray-70, although most of this difference can probably be attributed to the presence of the compost. The compost plus Enduraseal subplots had the highest values of perennial frequency. Very few significant effects on the canopy coverage of either the weeds or cheatgrass were found. The trends for the weeds are similar to those of the perennial grasses, though the differences are usually not statistically significant. The cheatgrass coverage is slightly higher in the compost plots, and slightly lower in the soil sealant plots; however, none of these trends is statistically significant. From visual observations of the test plots, one would have expected the compost plots to have much more cheatgrass than the noncomposted plots. Measurements of actual biomass production may have supported this contention better than the canopy coverage measurements; however, these measurements were not initiated until 1993.

These initial plant community measurements indicate that compost has a distinct beneficial effect on the development of perennial grasses. The soil sealants do not appear to have as much of an effect. Cheatgrass also appears to benefit from the presence of compost.

Second Year Plant Community Measurements

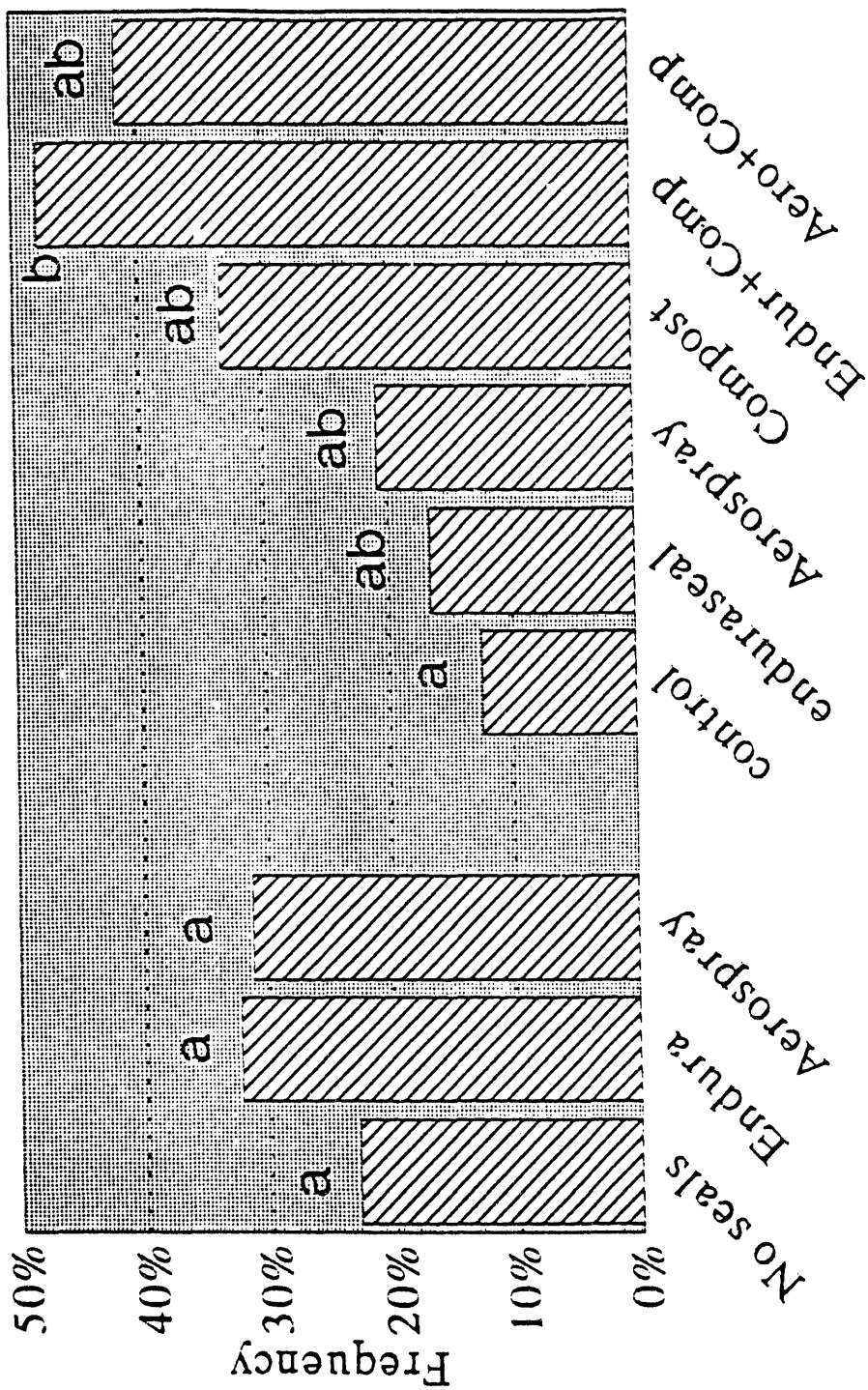
Since the survivorship of the perennial grasses into the second growing season was fairly low and sporadic, and since the cheatgrass cover was fairly heavy throughout the test plots, the plant community was sampled as total plant biomass and total coverage in June 1993. Total plant coverage was determined using a 20 cm by 50 cm plot-frame, placed at ten points within each of the surface treatment combinations in all six of the whole plots. Total coverage within each plot-frame position was visually estimated and assigned a coverage class value between 0 and 6. The ranges of coverage for each coverage class were: 0% = cover class 0, <5% = cover class 1, 5% - 25% = cover class 2, 25% - 50% = cover class 3, 50% - 75% = cover class 4, 75% - 90% = cover class 5, and >95% = cover class 6. After a coverage class was determined, an estimate was made of the relative proportion of grass (cheatgrass plus perennial if present) and weeds in the coverage.

Total plant biomass production was estimated by collecting all of the vegetation within three randomly selected 10 cm by 10 cm squares in each of the treatment plots. The plant material was then oven dried to constant weight, and the dry weight was determined.

Second Year Results

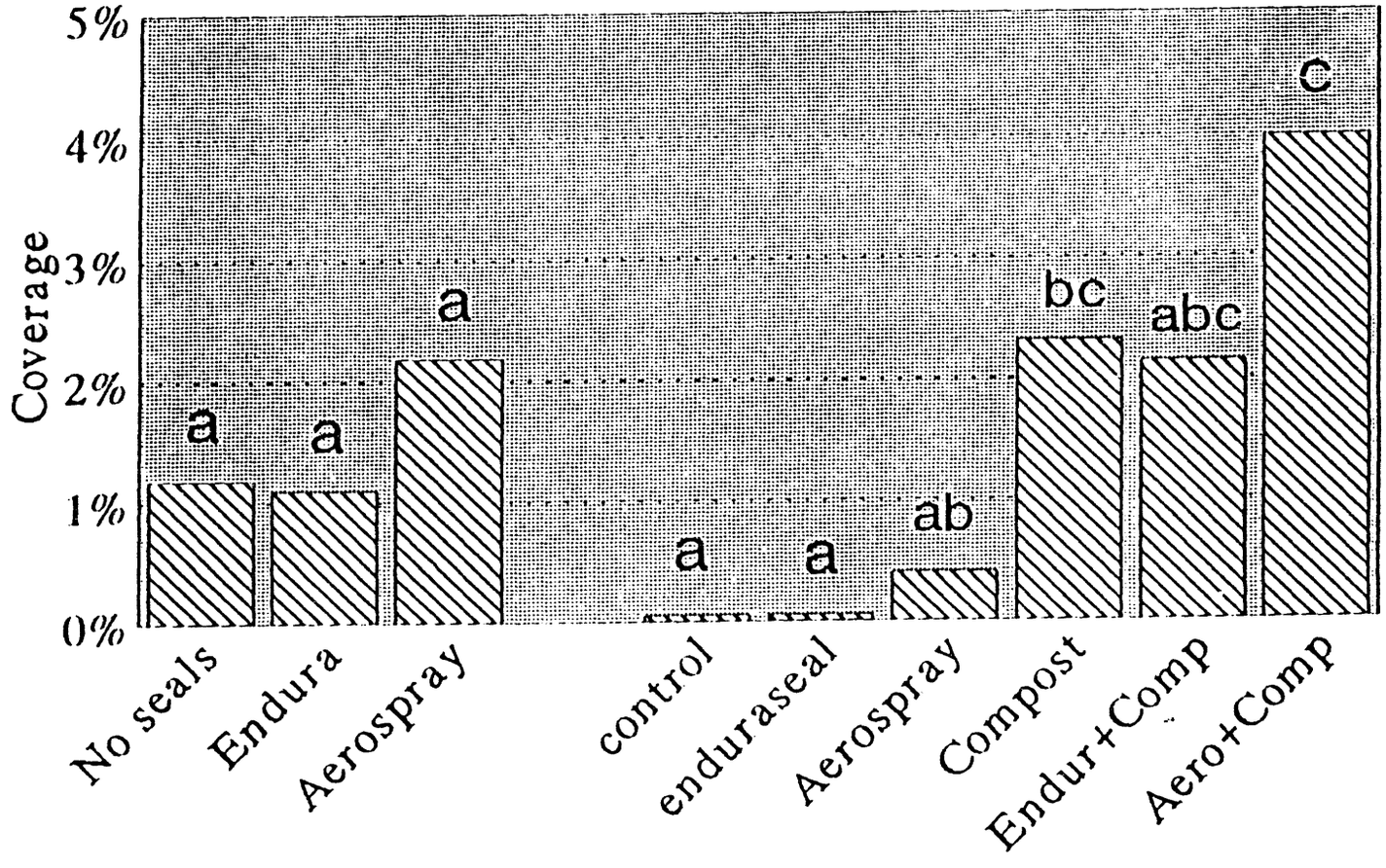
These estimates of plant coverage are by nature qualitative; therefore, no rigorous analyses of these results were pursued. However, several conclusions can readily be drawn from these data. No real differences in total plant coverage were seen among the different soil sealant types. Second, plots that were composted had much greater total plant coverage than the plots without compost. The composted plots had an average cover class of approximately 5 while the noncomposted plots had an average cover class of

Figure 9. June 1992 Perennial Frequency - Soil Sealants Effects.



Bars within a grouping marked with the same letter are not significantly different at $p \leq 0.05$.

Figure 10. June 1992 Perennial Coverage - Soil Sealant Effects.



Bars within a grouping marked with the same letter are not significantly different at $p \leq 0.05$.

Figure 11. Total Plant Coverage Class.

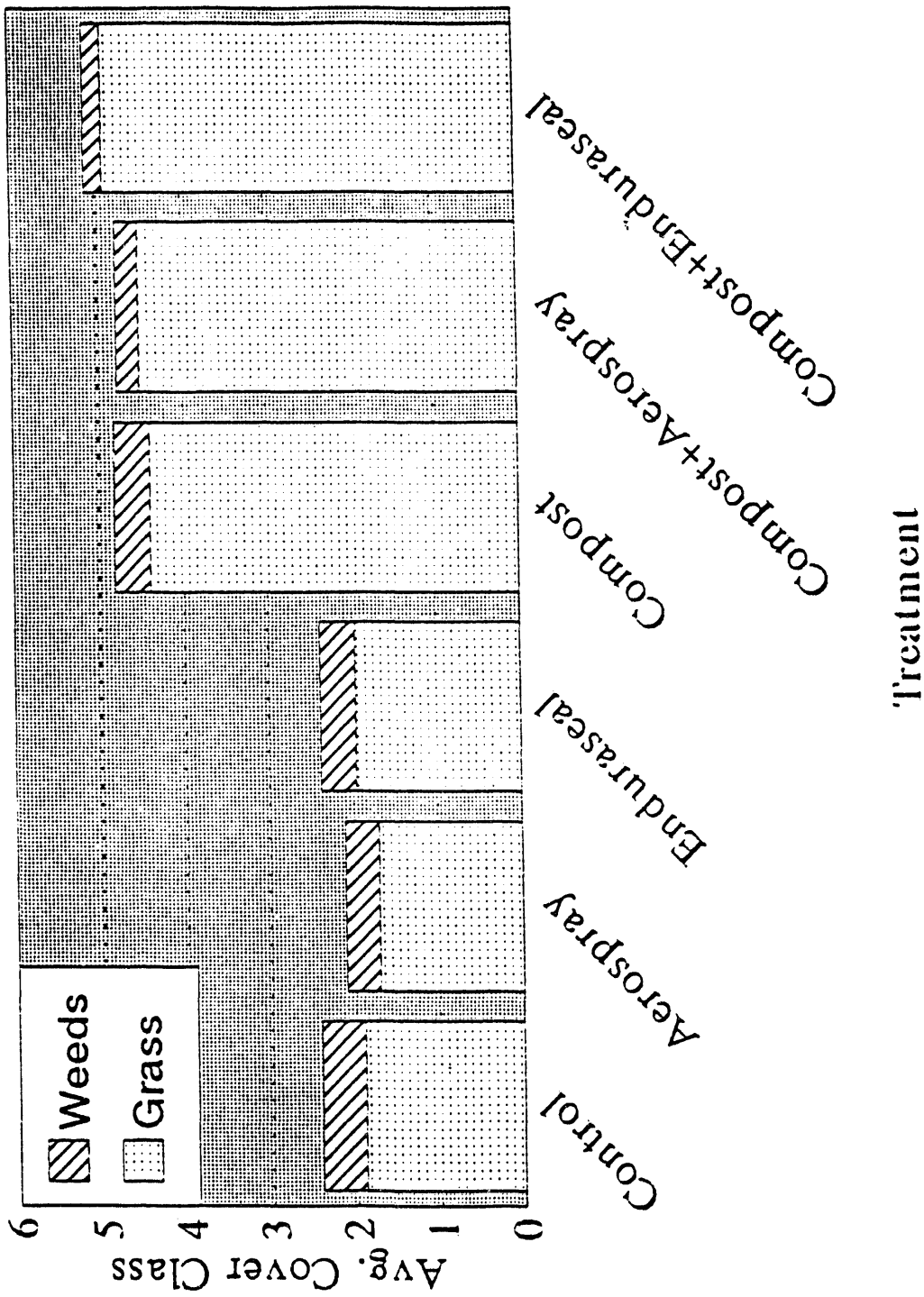
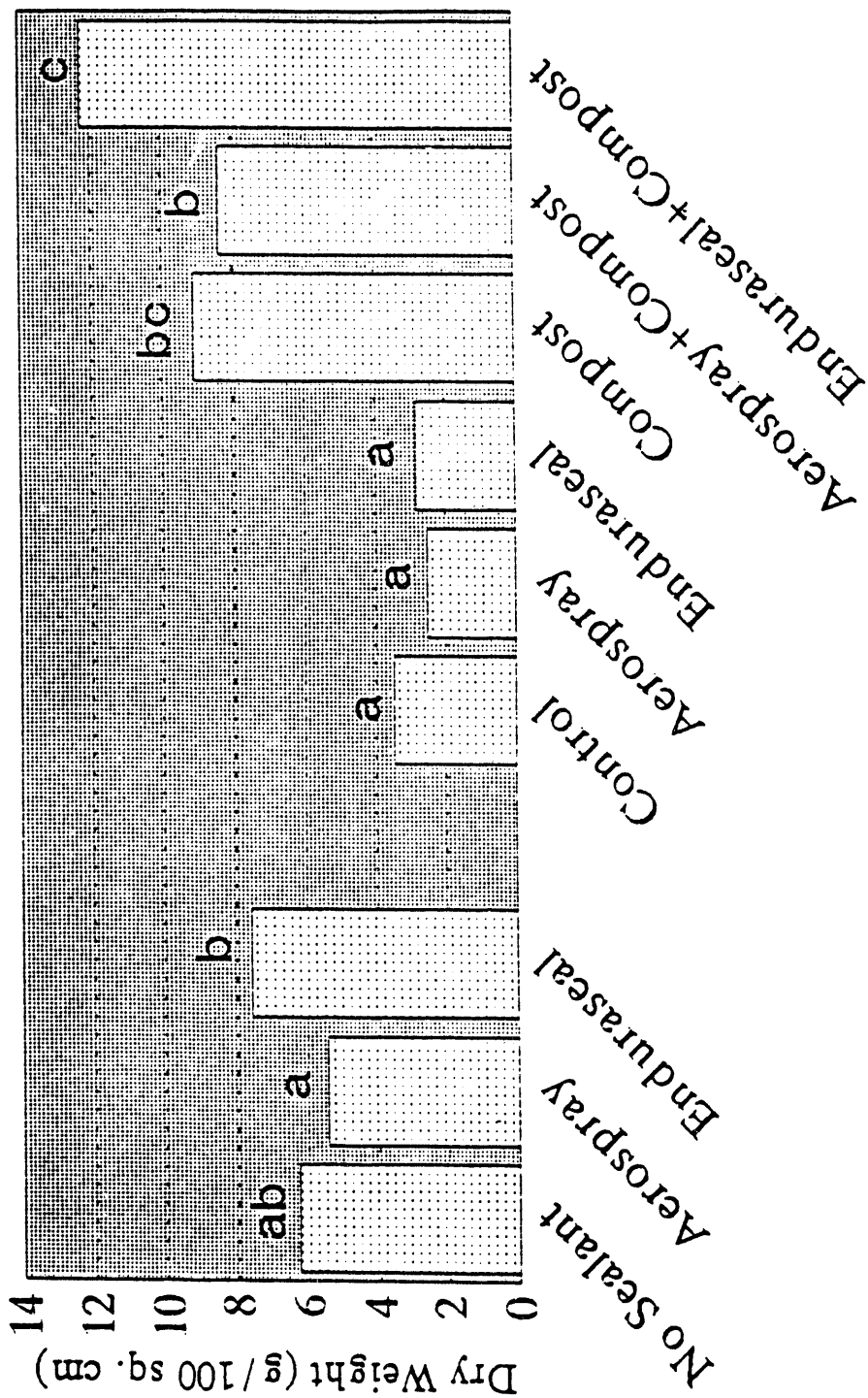


Figure 12. Total Plant Biomass, June 1993 - Soil Sealant Effects.



Bars within a grouping with the same letter are not significantly different ($p<0.05$)

slightly over 2. Figure 11 shows the average total plant coverage class for the six different surface treatment combinations, along with an indication of the relative proportion of the coverage made up of either grass or weeds. In the noncomposted plots weeds contributed approximately 20% of the total plant coverage, while in the plots with compost weeds only contributed about 10%.

Figure 12 shows the effects of the different soil sealant treatments on total plant biomass. It was found that plots with a combination of Enduraseal and compost had the greatest amount of biomass production.

CONCLUSIONS

During the first year of testing all sites with compost provided additional fertility and retained a greater amount of soil moisture than noncomposted sites. It was also found that the use of Enduraseal soil fixative provided greater soil moisture than the use of Aerospray-70 soil fixative. During the second year of soil moisture testing, the use of compost and soil fixatives had a lesser effect on soil moisture. During late summer periods all treatments had very similar soil moisture profiles resulting from evaporation and plant transpiration. The use of compost greatly increased vegetative cover and soil fertility in comparison to sites that had no compost added. Biomass production was significantly greater on plots with compost than on the noncomposted plots. While no significant erosion or erosion caused plant loss was observed during the study period, the successful establishment of viable plant cover on susceptible arid sites can be aided by the use of compost.

REFERENCES

Brandt, C. A. and P. L. Hendrickson. 1990. Review of Municipal Sludge Use as a Soil Amendment on Disturbed Lands. PNL-7425. Pacific Northwest Laboratory. Richland, Washington.

Brandt, C. A., W. H. Rickard Jr. and N. A. Cadoret. 1991. Reclamation Report Basalt Waste Isolation Project Boreholes 1990. PNL-7585. Pacific Northwest Laboratory. Richland, Washington.

Cox, G. R. 1981. First Year Evaluation of Low-Level Waste Management Stabilization Techniques. RHO-LD-143. Rockwell Hanford Operations. Richland, Washington.

Sackschewsky, M. R., C. J. Kemp and W. M. Hayward. 1993. Surface Stabilization and Revegetation Test Plots - FY 1993 Status Report. WHC-EP-0864. Westinghouse Hanford Company. Richland, Washington.

Tisdale, Samuel L. and Werner L. Nelson. 1975. Soil Fertility and Fertilizers. Third Edition, McMillan Publishing Co. Inc. Chapters 5, 6, 7,and 8.

Tucker, Ray M., Revised by, 1985, The LaMotte Soil Handbook, LaMotte Chemical Products Company, pages 5 through 59.

DATE
FILMED
10/12/94

END