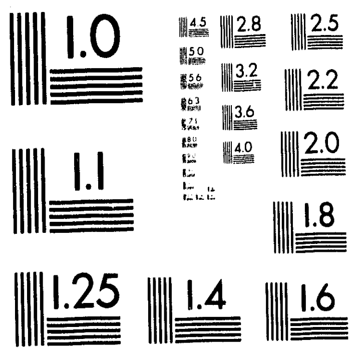

1.0
4.5
2.8
2.5
5.0
5.6
3.2
2.2
6.3
3.6
7.1
8.0
4.0
2.0
1.1
1.8
1.25
1.4
1.6

WHC-EP-0684

UC-602

Surface Stablization and Revegation Test Plots

Fiscal Year 1993 Status Report

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

Date Published
September 1993

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

ORIGINAL

INFORMATION RELEASE REQUEST

Date Received: ~~09/08/93~~ 9/13/93 VB

Reference: WHC-CM-3-4

Complete for all Types of Release

Purpose		ID Number (include revision, volume, etc.)
[] Speech or Presentation (Check only one suffix): [] Full Paper; [] Summary; [] Abstract; [] Visual Aid	[] Reference	WHC-EP-0684
[] Speakers Bureau	[X] Technical Report	List attachments.
[] Poster Session	[] Thesis or Dissertation	
[] Videotape	[] Manual	Date Release Required
	[] Brochure/Flier	
	[] Software/Database	
	[] Controlled Document	
	[] Other	

Title: Surface Stabilization and Revegetation Test Plots FY 1993 Status Report

Unclassified Category: UC-602

Impact Level: 4

New or novel (patentable) subject matter? [X] No [] Yes
If "Yes", has disclosure been submitted by WHC or other company?
[] No [] Yes Disclosure No(s).

Information received from others in confidence, such as proprietary data, trade secrets, and/or inventions?
[X] No [] Yes (Identify)

Copyrights? [X] No [] Yes
If "Yes", has written permission been granted?
[] No [] Yes (Attach Permission)

Trademarks?
[] No [] Yes (Identify)

Complete for Speech or Presentation

Title of Conference or Meeting

Group or Society Sponsoring

Date(s) of Conference or Meeting

City/State

Will proceedings be published? [] Yes [] No

Will material be handed out? [] Yes [] No

Title of Journal

CHECKLIST FOR SIGNATORIES

Review Required per WHC-CM-3-4	Yes	No	Reviewer - Signature Indicates Approval: Name (printed)	Signature	Date
Classification/Unclassified Controlled Nuclear Information	[]	[X]			
Patent - General Counsel	[X]	[]	SWBERGLID	[signature]	9/10/93
Legal - General Counsel	[X]	[]			
Applied Technology/Export Controlled Information or International Program	[]	[X]			
WHC Program/Project	[]	[X]			
Communications	[]	[X]			
RL Program/Project	[X]	[]	J. P. Collins	[signature]	9/20/93
Publication Services	[X]	[]	D. L. Crockford	[signature]	9/29/93
Other Program/Project	[X]	[]	W. M. Hayward	W. M. Hayward	9-9-93

Information conforms to all applicable requirements. The above information is certified to be correct.

	Yes	No
References Available to Intended Audience	[X]	[]
Transmit to DOE-HQ/Office of Scientific and Technical Information	[X]	[]

Author/Requestor (Printed/Signature) Date

C. J. Kemp [signature] 9-10-93

Intended Audience

[] Internal [] Sponsor [X] External

Responsible Manager (Printed/Signature) Date

J. W. Cammann [signature] for J. W. Cammann 9/9/93

INFORMATION RELEASE ADMINISTRATION APPROVAL STAMP

Stamp is required before release. Release is contingent upon resolution of mandatory comments.

APPROVED FOR RELEASE — OFFICIAL DOCUMENT — CW — Date 9-30-93

Date Cancelled

Date Disapproved

EXECUTIVE SUMMARY

Westinghouse Hanford Company Decommissioning and Decontamination Engineering Group and Environmental Technology and Assessment Groups are jointly developing new technologies to improve revegetation techniques for interim stabilization control over underground waste sites within the Radiation Area Remedial Action Program. Successful revegetation is an integral aspect of waste isolation strategy on these sites. Unfortunately, revegetation can be very difficult to achieve on the Hanford Site due to a number of factors, including the low amount of annual precipitation (average 16 cm/year), unpredictable timing of precipitation, low fertility of available soils, and coarse physical texture of soils used to cover waste sites.

The tests described in this report were performed during fiscal years 1992 and 1993 and involve the use of two soil sealants in combination with bare soil and a soil/compost mixture. Tests also included a comparison of a wheatgrass mixture, and a native seed mixture. Hydroprobe access ports were placed in one-half of the test plots and moisture data was collected from each of the treatments placed at the test site. The soil fertility and plant community characteristics were monitored periodically during the two years of the test.

During the first year of testing all sites with compost provided additional fertility and retained greater amounts of soil moisture than in noncomposted sites. Also, it was found that the use of Enduraseal soil fixative provided greater soil moisture than the use of Aerospray[1]-77 soil fixative. During the second year of soil moisture testing, the use of compost and soil fixative's had a lesser effect on soil moisture. During late summer periods all treatments had very similar soil moisture profiles, which resulted 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. Testing of the seed mixtures found that Siberian wheatgrass and Sandberg's bluegrass were the most dominant of the seeded species observed. All plots exhibited a dominant plant cover of volunteer cheatgrass. Biomass production was significantly greater on plots with compost than on the noncomposted plots.

---

[1]A tradename of American Cyamid.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF TERMS

CEC	cation ion exchange capacity
FY	fiscal year
PLS	pure live seed

Metric Conversion Table

ac x 43,500 = ft^2	in. x 2.54 = cm
ac x 4,047 = m^2	kg x 2.205 = lb
(°C x 9/5) + 32 = °F	km x 0.621 = mi
cm x 0.394 = in.	km^2 x 0.386 = mi^2
cm^2 x 0.155 = $in.^2$	L x 0.264 = gal
cm^3 x 0.061 = $in.^3$	lb x 0.454 = kg
(°F - 32) x 5/9 = °C	m x 3.281 = ft
ft x 0.305 = m	m^2 x 10.76 = ft^2
ft^2 x 0.093 = m^2	m^3 x 35.31 = ft^3
ft^3 x 0.028 = m^3	mi x 1.609 = km
gal x 3.785 = L	mi^2 x 2.59 = km^2

1.0 INTRODUCTION

The current Hanford Site practice for the stabilization of contaminated soil sites and retired burial grounds involves placing no less than 0.6 m (2 ft) of radiologically clean backfill over the contaminated surface, followed by revegetation. This procedure has resulted in the establishment of a viable plant cover at several locations. In other cases, however, these efforts have failed to establish healthy shallow rooted grass coverage. Unsuccessful revegetation results in increased total costs of stabilization, because the reseeding efforts must be repeated. In addition, an unsuccessful stabilization effort may result in greater 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, including the following:

- Inadequate and sporadic natural precipitation
- Windy conditions that produce large erosive forces
- Soils that are low in nutrients and organic matter
- Invasion of disturbed sites by aggressive, weedy annuals
- Limited supplies of quality topsoil.

Previous work (Cox 1981) that led to the currently used revegetation methodology has shown that Russian thistle 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. A partial remedy is to stockpile the upper layer of soil from each borrow activity, and only use the lower soil horizons for backfill. However, the amount of stockpiled soil will be considerably less than is needed for future restabilization efforts. Part of the efforts of the work described in this document is aimed at improving low-quality borrow site material with the use of composts and or soil sealants. The work described this report is designed to address the remaining environmental issues (i.e., soil moisture, erosion, and soil nutrients) with the objective of developing revegetation and restabilization procedures that will have a higher probability of success than current practices.

1.1 SOIL MOISTURE

The soil water balance of a surface with limited vegetation can be described by the equation:

$$P = E + D + R + S$$

where:

P = Precipitation
E = Evaporation
D = Deep drainage
R = Runoff
S = Storage in the soil column.

Successful establishment of vegetation at an arid site such as the Hanford Site requires that the amount of plant available soil moisture (i.e., storage) be maximized. This can be accomplished by increasing the amount of precipitation and/or decreasing the amount of evaporation, drainage or runoff. In most of the sites of interest at Hanford, the deep drainage and runoff terms will be negligible, therefore storage can be controlled through manipulation of either precipitation or evaporation.

An obvious means of addressing the problem of limited precipitation is to provide supplemental irrigation. This would necessitate relatively large capital investments in piping, pumps, and nozzles, as well as relatively high labor requirements for the installation and operation of the equipment. A cost effective alternative means of increasing the amount of plant available soil moisture is to reduce the amount of surface evaporation.

There are several available approaches that can be used for limiting surface evaporation. Surface gravel veneers, have been shown to decrease surface evaporation and increase soil water storage (i.e., Sackschewsky et al. 1993). The surface veneer should consist of small diameter gravel (about 0.64 cm [1/4 in.]) placed 2 to 3 layers deep. Thicker gravel mulches are not recommended because of adverse effects on plant establishment, and concerns of increasing deep drainage and subsequent leaching of the underlying contaminants. A side benefit of gravel veneers is the reduction in wind and water erosion. The effect of a thin gravel veneer on plant establishment has not been fully documented.

An alternative approach uses commercially available soil sealants made of organic polymers or wood by-products. These products are typically marketed for uses ranging from dust suppression to paving road surfaces. These products also can be used produce a non-erodible surface that will minimize the amount of evaporation. Using high application rates, the resulting crust can support light vehicles, such as the mobile radiation monitoring equipment. If the sealants are applied properly, seed can be drilled directly through the sealant crust. The remaining sealant material would continue to provide some erosion protection and may direct precipitation into the drill furrows, thus acting as a small scale water harvesting system. There are two primary negative concerns about the use of soil sealants. First, some products could be considered hazardous materials either now or in the future (although there are several products that appear to be safe). Second, the presence of soil sealants may create problems during future soil washing operations. This should not be a major concern if enough time elapses between the time of sealant application and the time of final soil remediation. Most soil sealants will degrade naturally. Two soil sealants, Aerospray[1]-70 (an organic polymer) and Enduraseal (a wood-sap by-product) have been incorporated into the set of revegetation test plots. Both of these products are readily available and the manufacturers claim that they can be used for these purposes.

[1]A tradename of American Cyamid.

1.2 EROSION CONTROL

Wind erosion can result in the loss of topsoil, increased evaporation, and possibly exposing and decimating the seeds. Wind blown particulate can severely damage seedlings. These processes can be controlled by using surface gravel veneers, soil sealants, or a crimped straw or hay mulch. Straw or alfalfa mulch is currently used on many restabilized sites at Hanford. The primary advantages of mulching is increased soil organic matter, water retention, and erosion protection. The primary advantage to using alfalfa instead of straw is the high carbon to nitrogen ratio within straw. In the experiments discussed in this report, only soil sealants and a compost amendment are used for erosion protection. Future expansion of these tests may include the use of crimped alfalfa or grass hay mulches alone or in conjunction with soil sealants.

1.3 SOIL NUTRIENTS AND ORGANIC MATTER

Topsoil on the Hanford Site are typically very low in both organic matter (usually less than 1%) and nutrients needed for plant growth. This is compounded by the scarcity of topsoil borrow sites near the locations of restabilization, subsoils from borrow sites are lower in nutrient status than existing topsoil. Subsoil that is used for restabilization can be amended with high nitrogen organic materials such as manure or composted sewage sludge. Sewage sludge compost can increase the soil organic matter content, tilth, cation exchange capacity, and plant available nitrogen in nutrient poor soil. Additional benefits include an increase in soil bacterial action, therefore the sludge or compost can serve as an inoculum of mycorrhizal fungi. Mycorrhizae fungi form symbiotic relationships with many plants, therefore greatly increasing the water and nutrient uptake abilities of the plant roots. Perennial and annual grass species require mycorrhizae for growth and survival. Experiments described in this report are designed to examine the effects of a commercially available composted sewage sludge (i.e., GroCo[1]) on plant establishment, growth, and survival.

1.4 SELECTION OF PLANT SPECIES

The majority of revegetation projects on the Hanford Site have used a mixture of Siberian wheatgrass (*Agropyron sibericum*) and Thickspike wheatgrass (*A. dasytachyum*). Occasionally, Crested wheatgrass (*A. cristatum*) has been used exclusively or added to the mix. Of these, only thickspike wheatgrass is actually native to the Hanford Site. The wheatgrass mixture has worked well at several sites. However, there are a number of drought tolerant bunchgrass species that are native to the Hanford environment and are commercially available. Although seed for some of these native species are more expensive in comparison to wheatgrass seed, they offer several potential advantages. Because of their natural presence on the Hanford Site, they can be assumed to

[1]A tradename of Seattle Metro.

be well adapted to the local conditions. If a mixture of several species is established, the plant community may have increased disease resistance. A diversity of plant species may partition resources more effectively because intraspecific competition is normally stronger than interspecific competition.

1.5 DESCRIPTION OF TESTS

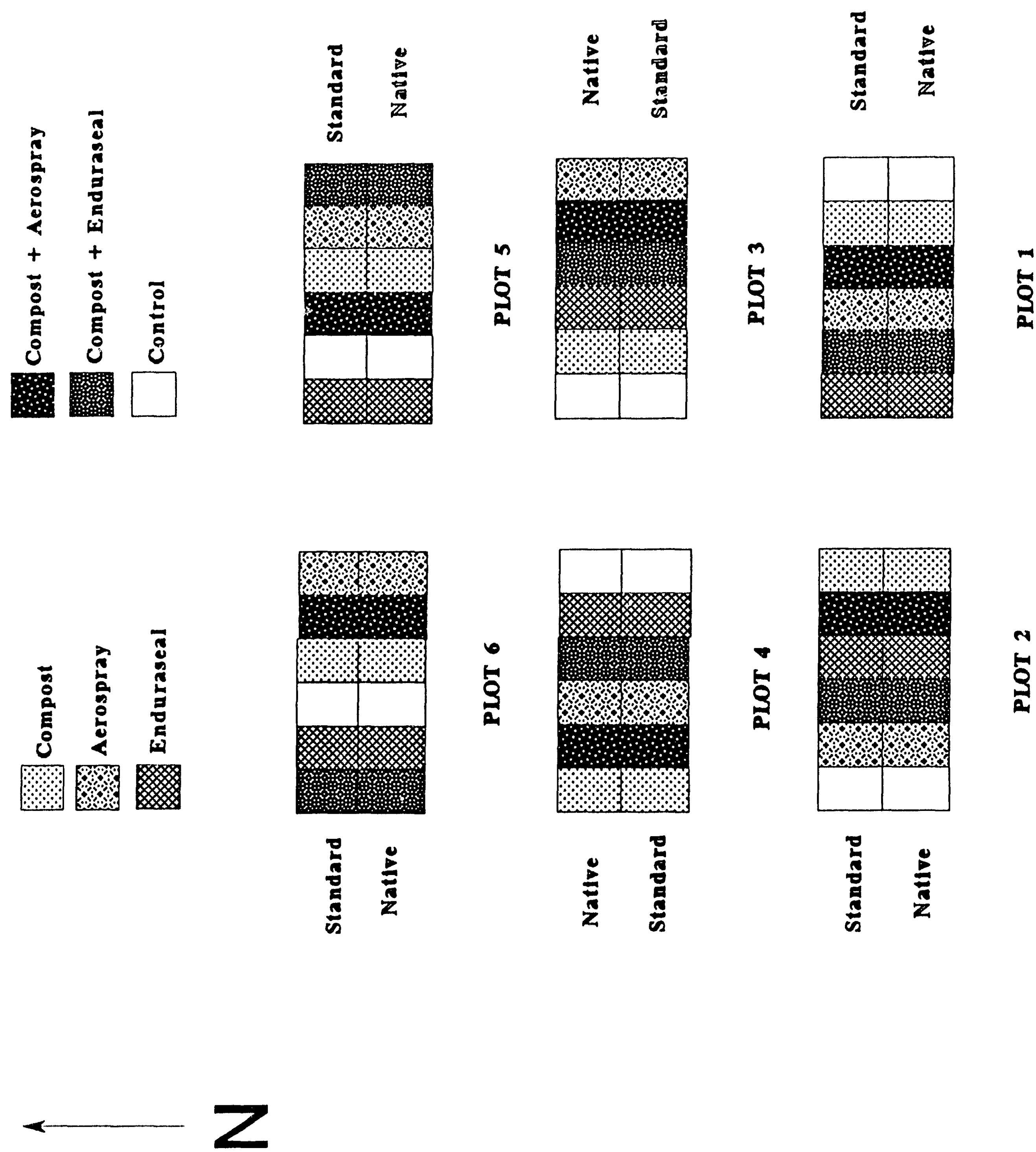
The tests described in this report are designed to investigate the effects of soil sealants, composted sewage sludge, and alternative species mixes on the success of revegetation efforts. Composted sewage sludge was applied to test its effects on the amounts of plant available nutrients, the water holding capacity of the soil, and the amount of organic matter in the soil matrix. Light applications of soil sealants were used to examine their utility for interim erosion protection and whether they decrease the rate of evapotranspiration from the soil surface. Theoretically, if both compost and soil sealants are provided, the combination of these effects should provide a greater soil moisture, and nutrient rich environment for plant growth and development than under untreated soil conditions. Over these soil treatments two different mixtures of seed were applied, a "standard mix" of Siberian and Thickspike wheatgrass, 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) 1993 included plant coverage, total plant aboveground biomass, monthly soil moisture monitoring using neutron activation, and soil nutrient status.

2.0 COMPOST/SOIL SEALANT TEST PLOT CONSTRUCTION

Test plots to examine the effects of compost and two different soil sealants on the germination and growth of perennial bunchgrasses were set-up during July and August of 1991. The location of the test plots is directly north of the 218-E-10 burial ground in the 200 East Area. Activities included surveying the plots, preparing the surfaces, applying the compost and soil sealants, installing neutron probe access ports, and planting seed.

The area chosen for these test plots was an area that had been stripped of topsoil during the spring of 1991 for the remediation of a nearby contaminated site. After the top soil was removed, Kaiser Engineers Hanford surveyed the plots on June 14, 1991, and the plots were staked out. Following the plot survey, 25 m^3 (300 yd^3) of compost was delivered and spread to a depth of 11.4 cm (4.5 in.) by an offsite vendor on one half of the strips from June 17-18, 1991. Aerospray®-70A was applied with a hand operated airless-sprayer at a rate of 0.1 gallon of product/ft^2 in a 1:1 product:water mix during the period of June 21-25, 1991. Enduraseal (a.k.a., Envirobinder) was applied by an offsite vendor on June 25, 1991. The application rate could not be accurately determined but is calculated to also be approximately 0.1 gallon product/ft^2. The final surface treatment layout is provided in Figure 2-1.

Figure 2-1. Plot Construction.



Neutron probe access ports were installed on August 23, 1991. Each 1-m (3.3-ft) thick wall aluminum tube was 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. Attempts to hand or machine auger the holes failed because of the subsoils' rocky nature. A total of 36 access ports were installed in plots 2, 3, and 6.

Seed was drilled on September 17, 1991. One half of each plot was seeded with a mixture of Siberian and Thickspike Wheatgrass ("Standard Mix"), planted at a rate of 15 lb pure live seed (PLS)/acre. The other half of each plot received a mixture of Indian Ricegrass, Needle-and-Thread Grass, Bottlebrush Squirreltail, Sandberg's Bluegrass, Sheep Fescue, and Thickspike Wheatgrass ("Native Mix") in equal proportions at a total rate of 21 lb PLS/acre. Ammonium Phosphate fertilizer was co-applied with the seed at a rate of 125 lb/acre, equivalent to 20 lb Nitrogen/acre.

3.0 SOIL FERTILITY MEASUREMENTS

3.1 BACKGROUND

Soils vary widely in their composition depending on their origin, time, and the natural forces involved in their formation process. Soil testing is an important management tool required for maintaining proper chemical balance within the soil and optimizing its use as a growth medium. Mineral soils are composed of three major constituents, sand, silt, and clay. A fourth component of soil is organic matter, although important in the biological and chemical makeup of some soils, is a very minor portion of arid Hanford Site soils. A useful method of increasing the organic matter content in a soil are amendments of organic materials.

The different components of soil are referred to as fractions (i.e., sand, silt, clay, and organic fractions). The colloidal portion of soils (i.e., sub-microscopic particle sizes with large surface area) consisting of clay particles and organic matter, account for a soil's capacity to hold nutrient elements. The minute clay and organic colloids have a negative charge and attract and hold positively charged nutrient elements such as calcium, magnesium, potassium, iron, manganese, zinc, and copper. These positively charged elements are called "cations" and the capacity of a soil to hold such cations is referred to as the cation ion exchange capacity (CEC). Plants require several elemental nutrients for survival and growth. Those that are required in relatively large amounts are termed macronutrients, while those that are required in relatively low amounts are micronutrients. Some elements that are essential for plant survival can become toxic if the concentration are too high. A soil's CEC and the concentration of elements within the soil matrix can be determined by chemical extraction.

The major essential macronutrients that plants obtain from soil are Nitrogen, Phosphorus, Potassium, Calcium, Magnesium, and Sulfur. Macronutrients required for plant growth that are derived from water and the atmosphere include the following: Carbon, Hydrogen, and Oxygen. The plant macronutrients absorbed from soil are supplied by the following processes:

- Decomposition of inorganic materials from native soil
- Deposition of water onto soil
- Treatments of chemical and/or organic fertilizers
- Decomposition of organic matter.

Plants are able to use most of their Nitrogen in the NH_4^+ and NO_3^- forms. In Hanford Site revegetated areas, most of the plant available Nitrogen is derived from chemical fertilizers, mineralization of Nitrogen, and conversion of Ammonia to Nitrite and then Nitrate by *Nitrosomonas* and *Nitrobacter* bacteria. The conversion of Ammonia to Nitrite and then Nitrate is referred to as nitrification and the bacteria involved in this are referred to as *Nitrobacteria*. Phosphorus is used by plants in available P_2O_5 form and is available in Hanford Site arid soils as $CaPO_4$. Potassium is available to plants as K^+ and is present in soils as K_2O. Exchangeable Calcium (Ca^{++} is present in Hanford Site soils mostly within $CaCO_3$ salts cemented to soil particles and is formed with water reacting with Calcium salts. Magnesium is often a companion with Calcium salts and is crucial to the photosynthetic cycle within a plant. Sulfur is available to the plant in the sulfate form SO_4^{--}.

The role of some micronutrients in plant growth are not completely understood, but these elements are clearly known to be essential for healthy growth. Manganese is most likely to occur in pH neutral or alkaline soils and can be leached in acidic, poor CEC soils. Iron is abundant in soils with iron salts, but only a small fraction is available to plant growth. If iron is needed it should be artificially applied in chelate form for greater plant availability. In addition several micronutrients exist in soils such as boron, copper, zinc, molybdenum, and chlorine. Trace nutrients required in minute quantities by some species include the following: cobalt, iodine, fluorine, sodium, lithium, and aluminum.

3.2 FISCAL YEAR 1992 TEST PLOT SOIL FERTILITY TESTING

Soil fertility samples were taken three times during FY 1992 (i.e., November, May, and August). 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; and in late summer, following the period of annual grass die-off. These samples were to quantify and characterize nutrient status in the first full year of growth. Samples taken from each of the compost/soil sealant test treatments. The soil samples were analyzed with a small, field portable, test kit available from Soil Testing Corporation. Exact soil fertility information would require testing by a certified soil testing laboratory, but the portable soil test kit is an accurate tool for obtaining data. Even with some accuracy limitations, the data collected with the test kit indicate some fertility differences related to the treatments used on the plots. The data from each of the analyses are provided in Tables 3-1 through 3-3.

Table 3-1. Soil Test Report Results.

Date Sampled: 11-17-91 Description: E-10 Plots Date Tested: 12-2-91

Element or property	Control	Control + Aerospray[1]	Control + Enduraseal	Compost	Compost + Aerospray®	Compost + Enduraseal
pH	8.0	8.0	7.8	6.6	6.4	6.6
Nitrate-N lb/acre	10	20	10	150	100	150
Phosphorus lb/acre	200	200	200	200	200	200
Potassium lb/acre	375	350	375	400	425	375
Humus	very low	very low	very low	medium	medium	medium
Calcium ppm.	>2800	>2800	>2800	>2800	>2800	>2800
Ammonia-N lb/acre	5	5	5	5	5	5
Magnesium ppm.	5	5	5	10	5	5
Manganese ppm.	<4	4	4	7	7	7
Aluminum ppm.	5	5	5	5	5	5
Nitrite-N lb/acre	<1	<1	<1	<1	<1	<1
Ferric Iron lb/acre	<5	<5	<5	<5	<5	<5
Sulfate ppm.	>2000	>2000	>2000	>2000	>2000	>2000

ppm = parts per million (p/M).

[1]A tradename of American Cyamid.

Table 3-2. Soil Test Report Results.

Date Sampled: 05-29-92 Description: E-10 Plots Date Tested: 06-22-92

Element or property	Control	Control + Aerospray[1]	Control + Enduraseal	Compost	Compost + Aerospray®	Compost + Enduraseal
pH	8.4	8.4	8.6	6.6	6.6	6.6
Nitrate-N lb/acre	<10	<10	<10	60	60	60
Phosphorus lb/acre	200	200	200	200	200	200
Potassium lb/acre	375	375	375	350	375	375
Humus	very low	very low	very low	medium	medium	medium
Calcium ppm.	2800	2800	2800	1400	1400	1400
Ammonia-N lb/acre	5	5	5	5	5	5
Magnesium ppm.	5	5	5	5	5	5
Manganese ppm.	4	4	4	4	4	4
Aluminum ppm.	5	5	5	5	5	5
Nitrite-N lb/acre	<1	<1	<1	<1	<1	<1
Ferric Iron lb/acre	<5	<5	<5	<5	<5	<5
Sulfate ppm.	>2000	>2000	>2000	>2000	>2000	>2000

ppm = parts per million (p/M).

[1]A tradename of American Cyamid.

Table 3-3. Soil Test Report Results.

Date Sampled: 08-29-92 Description: E-10 Plots Date Tested: 08-29-92

Element or property	Control	Control + Aerospray[1]	Control + Enduraseal	Compost	Compost + Aerospray®	Compost + Enduraseal
pH	8.2	8.0	8.4	7.0	6.6	6.6
Nitrate-N lb/acre	<10	<10	<10	60	60	60
Phosphorus lb/acre	200	200	200	200	200	200
Potassium lb/acre	375	350	375	350	350	375
Humus	very low	very low	very low	low	medium	low
Calcium ppm.	>2800	>2800	2800	>2800	1400	1400
Ammonia-N lb/acre	5	5	5	5	5	5
Magnesium ppm.	5	5	5	5	5	5
Manganese ppm.	4	4	4	4	4	4
Aluminum ppm.	5	5	5	5	5	5
Nitrite-N lb/acre	<1	<1	<1	<1	<1	<1
Ferric Iron lb/acre	<5	<5	<5	<5	<5	<5
Sulfate ppm.	>2000	>2000	>2000	>2000	>2000	>2000

ppm = parts per million (p/M).

[1] A tradename of American Cyamid.

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 are low, being limited by high or neutral soil pH and low CEC. Low micronutrient values may induce subtle changes in perennial grass growth and vigor but they are not normally major limiting factors for perennial grass establishment. Compost amended plots exhibit much higher levels of plant available nitrogen, in comparison to plots not treated with compost. Phosphorus, Potassium, Calcium, and Iron do 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 would provide any nutrients directly to the soil because of material compositions. Soil fertility values are correlated to the amount of grass growth on the different plot treatments.

3.3 FISCAL YEAR 1993 TEST PLOT SOIL FERTILITY TESTING

Soil fertility samples were taken once during FY 1993. This sampling period was performed in late spring (May) following the majority of 2 years of growth and germination. This sampling was to quantify and characterize nutrient status after 2 yrs of growth and germination of all plant species. Samples were taken from each of the compost/soil sealant, compost alone, soil sealants alone, and control test treatments. The soil samples were analyzed with a small, field portable test kit available from Soil Testing Corporation. Soil sampling results obtained from all plot treatments in FY 1992 had no significant differences in the following factors: Calcium, Magnesium, Manganese, Aluminum, Ferric Iron, and Sulfate. It is unlikely any of these factors and the relative amounts contained in the treatments resulted in significant effects on plant fertility needs. The soil fertility factors tested in FY 1993 included: soil pH, Nitrate Nitrogen, Phosphorus, Potassium, Humus, Ammonia Nitrogen, and Nitrite Nitrogen. Results of these analyses are provided in Table 3-4. 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 the low soil moisture available for Nitrobacteria activity and high Carbon to Nitrogen ratios in the soil organic matter. On the other hand, 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 the second year of the tests than plots with no compost. Many micro and trace nutrients become more readily available to plants with a reduction in soil pH. 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 would provide any nutrients directly to the soil because of material compositions.

Table 3-4. Soil Test Report Results.

Date Sampled: 05-7-93 Description: E-10 Plots Date Tested: 05-10-92

Element or property	Control	Control + Aerospray[1]	Control + Enduraseal	Compost	Compost + Aerospray®	Compost + Enduraseal
pH	8.4	8.2	8.2	7.0	6.8	6.8
Nitrate-N lb/acre	<10	<10	<10	<10	<10	<10
Phosphorus lb/acre	>200	>200	>200	>200	>200	>200
Potassium lb/acre	190	220	200	180	190	170
Humus	very low	very low	very low	high	high	high
Ammonia-N lb/acre	<5	<5	<5	5	5	5
Nitrite-N lb/acre	<1	<1	<1	<1	<1	<1

ppm = parts per million (p/M).

[1]A tradename of American Cyamid.

4.0 SOIL MOISTURE MEASUREMENTS

4.1 DESCRIPTION OF METHODS

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 was not collected were November 1991, and September 1992. The soil moisture data was performed using a Campbell Nuclear Corporation 503DR hydroprobe. The hydroprobe uses a 50 mCi Am^{241}/Be^{3} source that produces high energy neutrons and is therefore referred to as a neutron source. When the hydroprobe source is inserted into a 5-cm (2-in.) inside diameter pipe located below the soil surface it emits high energy neutrons into the soil. When high energy neutrons are placed into a soil medium they are slowed by Hydrogen atoms present in water. When the fast neutrons encounter Hydrogen they are slowed down into a lower energy, which is then measured using a He^{3} filled detector next to the neutron source. The detector response is relayed to an electronic measuring device and recorded as raw counts. This raw count is used to correlate soil moisture and is able to track trends for use in determining moisture changes within plot treatments.

The hydroprobe is calibrated using standards consisting of two 55-gal barrels filled with test plot soil placed below surface grade. One of the barrels was filled with air dry surface soil at the beginning of test in September 1991 and was rechecked in September 1992, when soil moisture is generally very low during the year. The other barrel had air dry soil wetted with additional water to near field capacity. The soil was then completely sealed within a plastic bag placed inside the barrels with a 5-cm (2-in.) inside diameter pipe located within the center. These barrels were then allowed to reach equilibrium for several days, and then three samples were then taken out of each, and then the barrels were resealed. These six total samples were oven dried and moisture content was determined according to WHC-IP-0635 manual procedure ETAL-14 (WHC 1990). This procedure corresponds directly to both American Society of Testing Materials (ASTM 1986) and American Soil Science Society Association procedures. 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. The barrels were placed below the soil surface grade to minimize any differences between ambient air and subsurface soil temperatures. A series of thirty-two 16-s hydroprobe counts was taken in each barrel using WHC-IP-0635 manual procedure ETBD-01 as guidance. A mean count from the series of raw counts in each barrel was determined and a graph slope was calculated between the dry and wet points. This graph slope line becomes the reference line and determines the moisture data and trends from the plots.

All treatments are measured monthly from three different whole plots (2, 3, and 6). During each monthly measurement period a set of standard measurements are gathered from the calibration barrels at both the beginning and end of the measurement period. A set of thirty-two 16-s counts are taken from the wet and dry soil standard barrels to determine if any misfunctioning of the electronics has or will occur during a set of readings. The standard readings are then calculated to determine a mean and chi-equivalent to ascertain the functioning of the instrument. After the first set of standard barrel measurements, all of the treatment plots within whole Plots 2, 3, and 6, are measured at depths of 90 cm (35 in.), 75 cm (30 in.), 60 cm (24 in.), 45 cm (18 in.), and 30 cm (12 in.). The raw count of each measurement is recorded within the electronic portion of the hydroprobe.

After a full set of readings and standards were taken, the electronic portion of the hydroprobe is disconnected and brought to a desktop computer. This electronic unit then "dumps" the raw count data into a spreadsheet format. Once the accuracy of the raw count data is determined, the data are converted into soil moisture by weight. The calculation from raw data % soil moisture is performed using the reference line from the standard barrel graph slope data. At no time during the year were temperature differences or moisture changes within the calibration barrels determined to provide any source of error with the measurement techniques used. Clearly, with the rocky heterogenous nature of the soils at the test plots, an exact soil moisture data point can only be determined by oven drying each soil sample. But the nondestructive method of soil moisture determination using the hydroprobe is accurate for the test plot experiment, and is very useful in determining the soil moisture trends.

4.2 SOIL MOISTURE RESULTS

The patterns of soil moisture content at each depth are provided in Figures 4-1 through 4-5. The soil water content at all depths was greatest during the late winter and early spring months of each year. 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 greater than 9% in all of the plots, except at the two deepest depths. 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 was analyzed further for 5 selected sampling dates: October 1991, February 1992, October 1992, March 1993, and August 1993. These dates were selected to correspond to the driest and wettest periods of the seasonal cycle. The data were analyzed as a Randomized Complete Block to test the effects of the 3 sealant treatments (Aerospray®, Enduraseal, and none), compost, and the interaction between these two effects, using the whole plots as the blocking variable. The analysis was conducted separately for each depth on each date. If, upon further monitoring, it becomes apparent that the type of seed mix may have an effect on the soil moisture then this effect can be added to the model. The only significant effect that was found in these analyses was that of compost, which had a highly significant effect on soil moisture at all depths during the October 1991 and February 1992 measurement periods. Mean soil water content values for the composted and noncomposted plots at each depth and measurement date are provided in Figure 4-6. The differences between the composted and non

Figure 4-1. Averaged Moisture Percent By Weight (30-cm Depth).

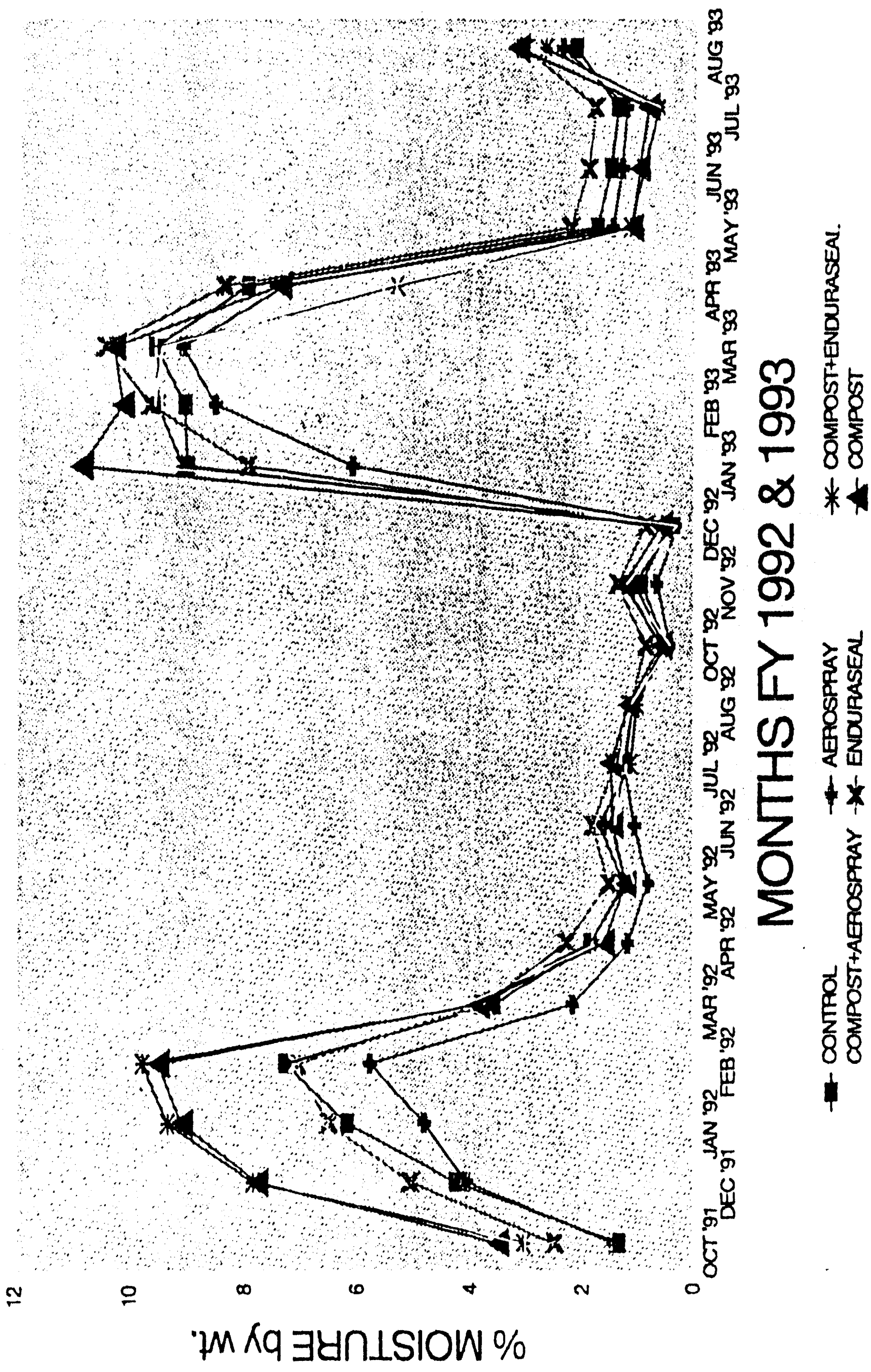


Figure 4-2. Averaged Moisture Percent By Weight (45-cm Depth).

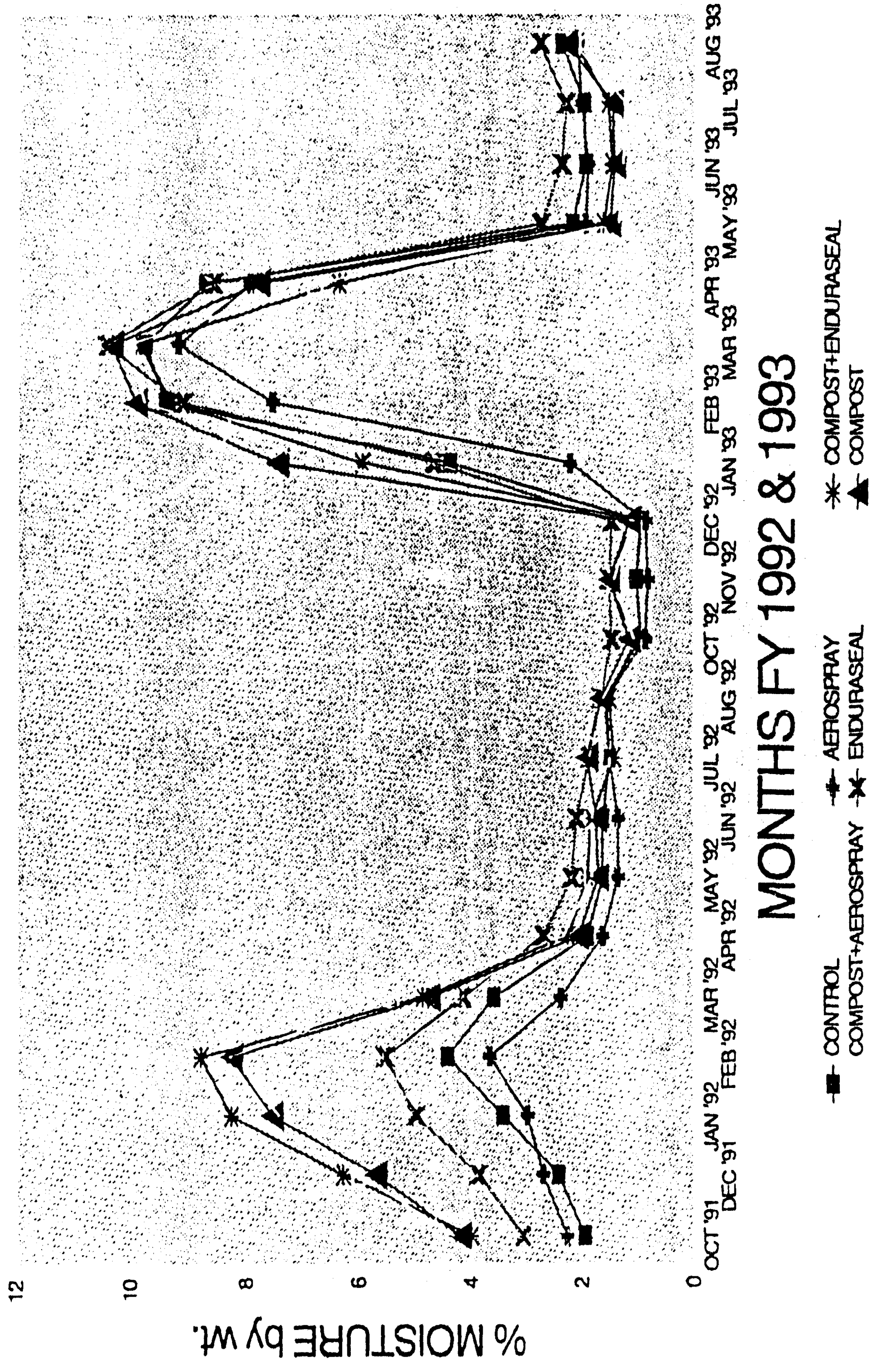


Figure 4-3. Averaged Moisture Percent By Weight (60-cm Depth).

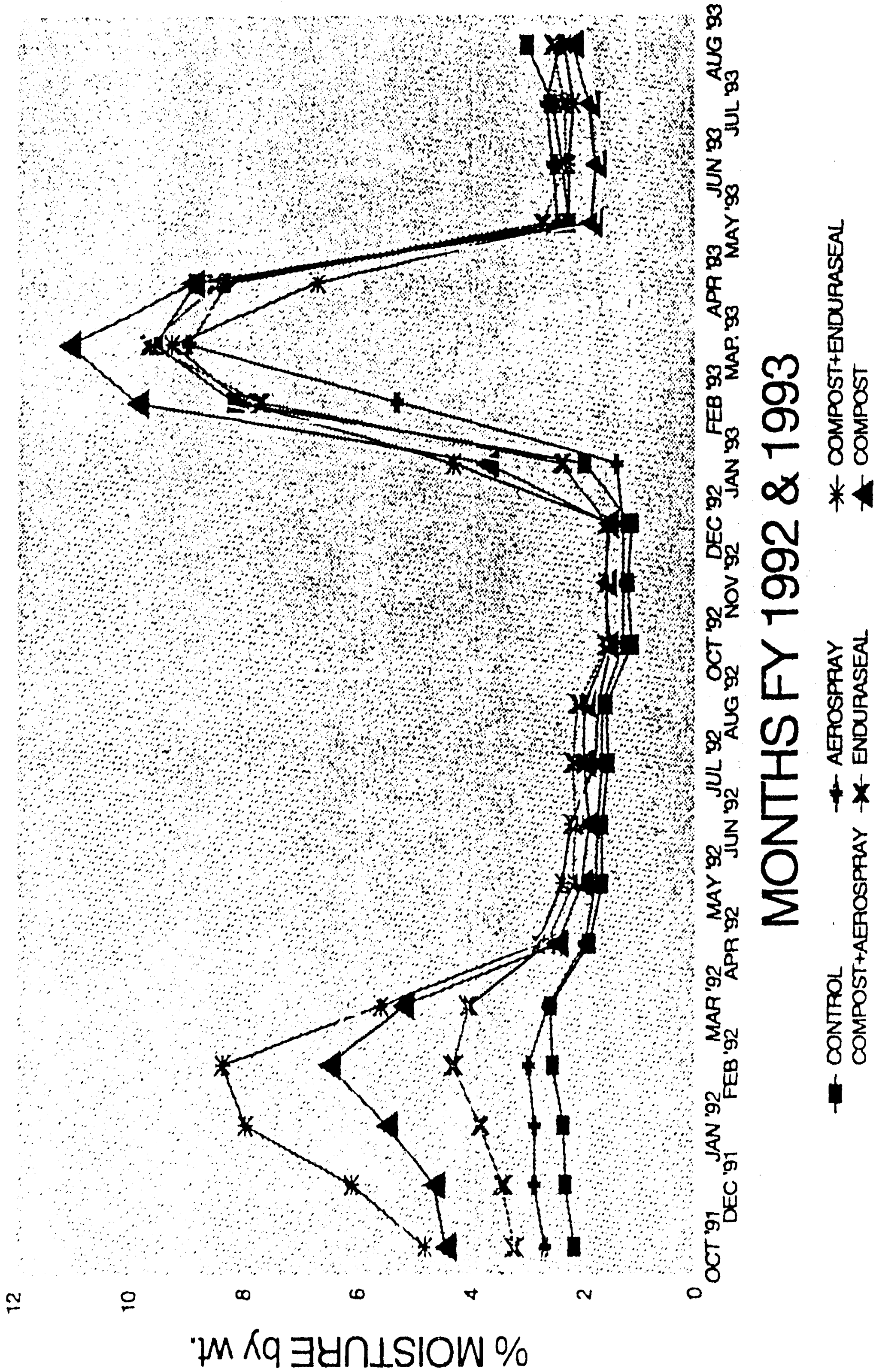


Figure 4-4. Averaged Moisture Percent By Weight (75-cm Depth).

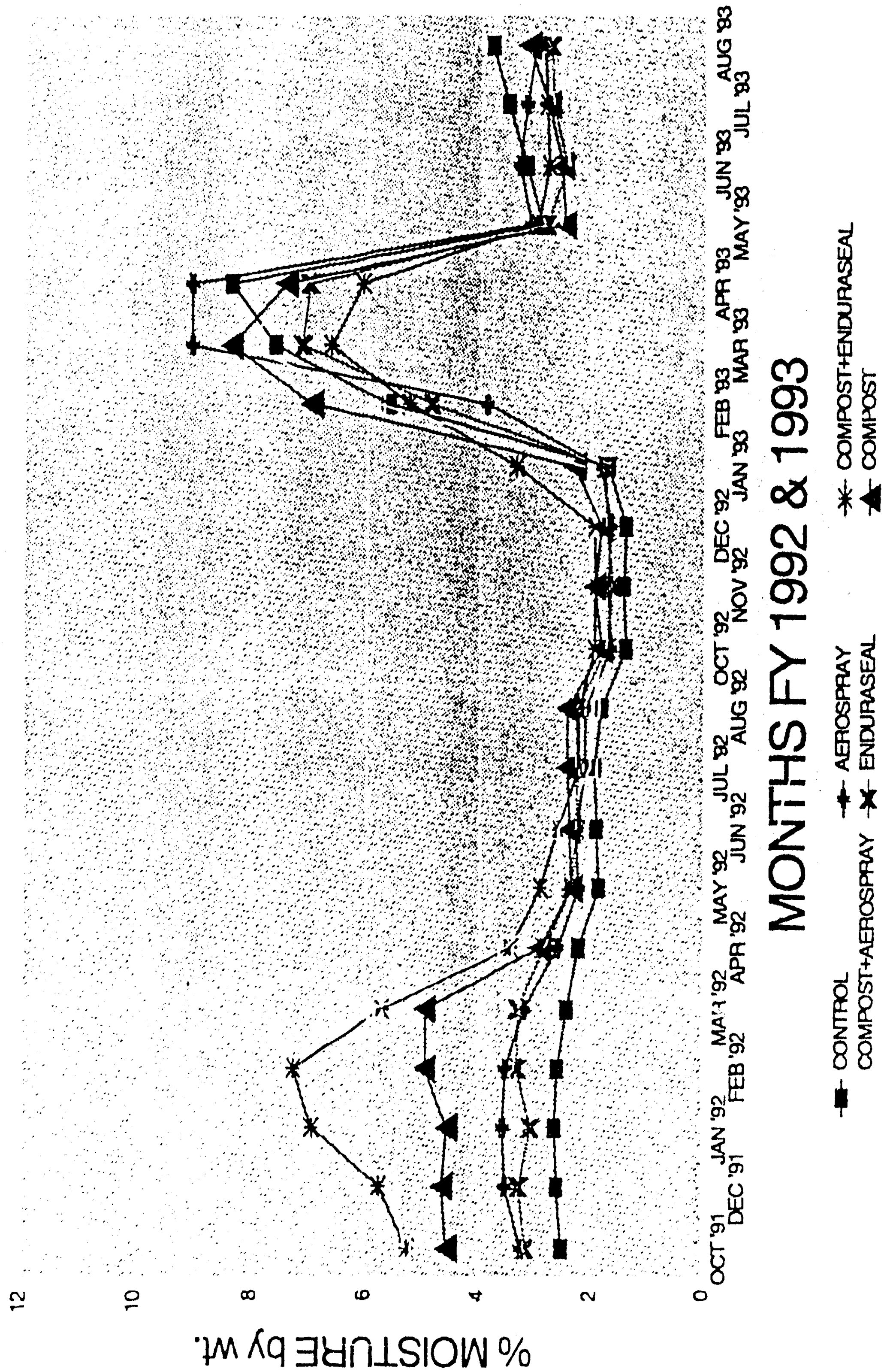
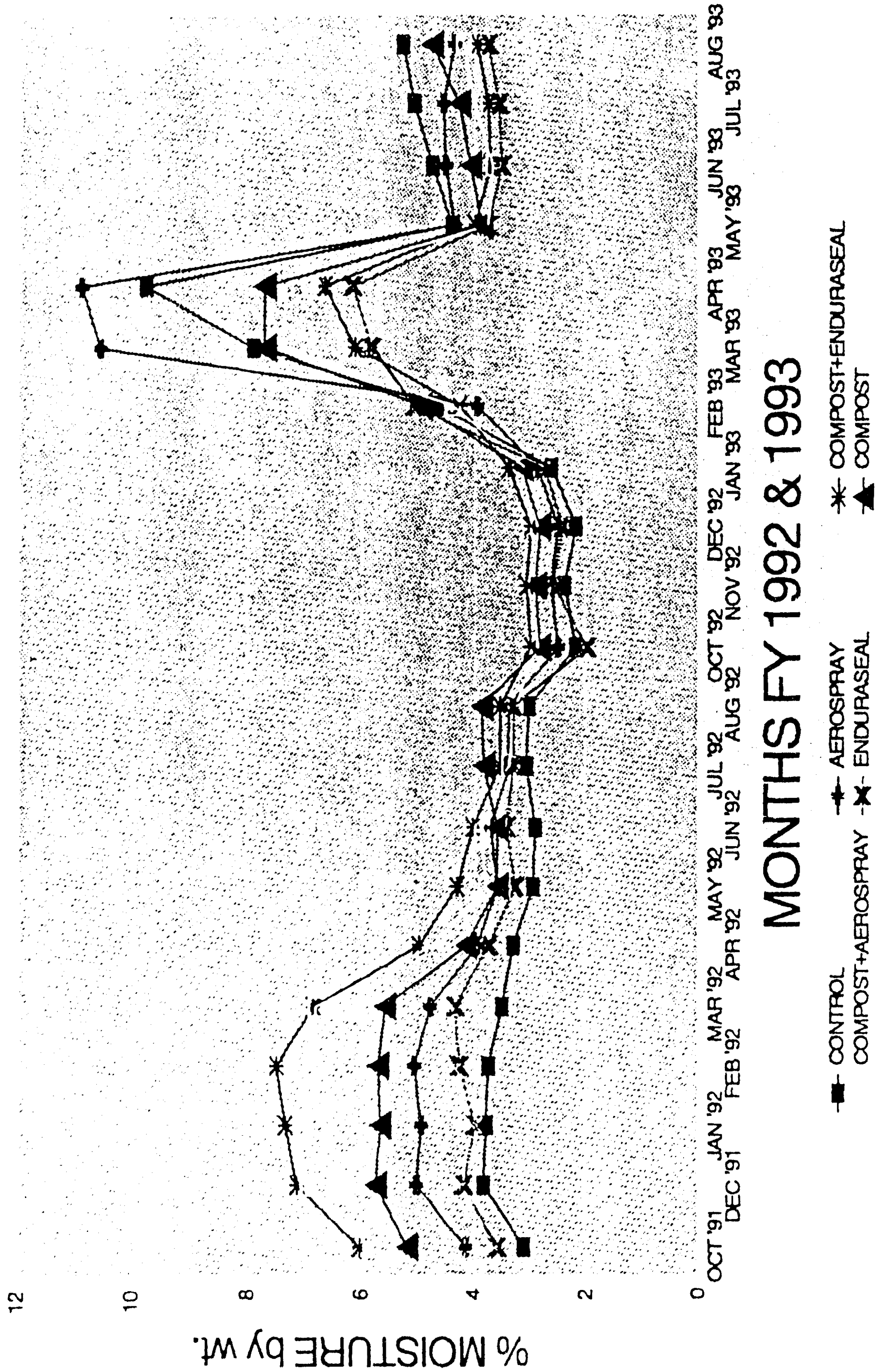


Figure 4-5. Averaged Moisture Percent By Weight (90-cm Depth).



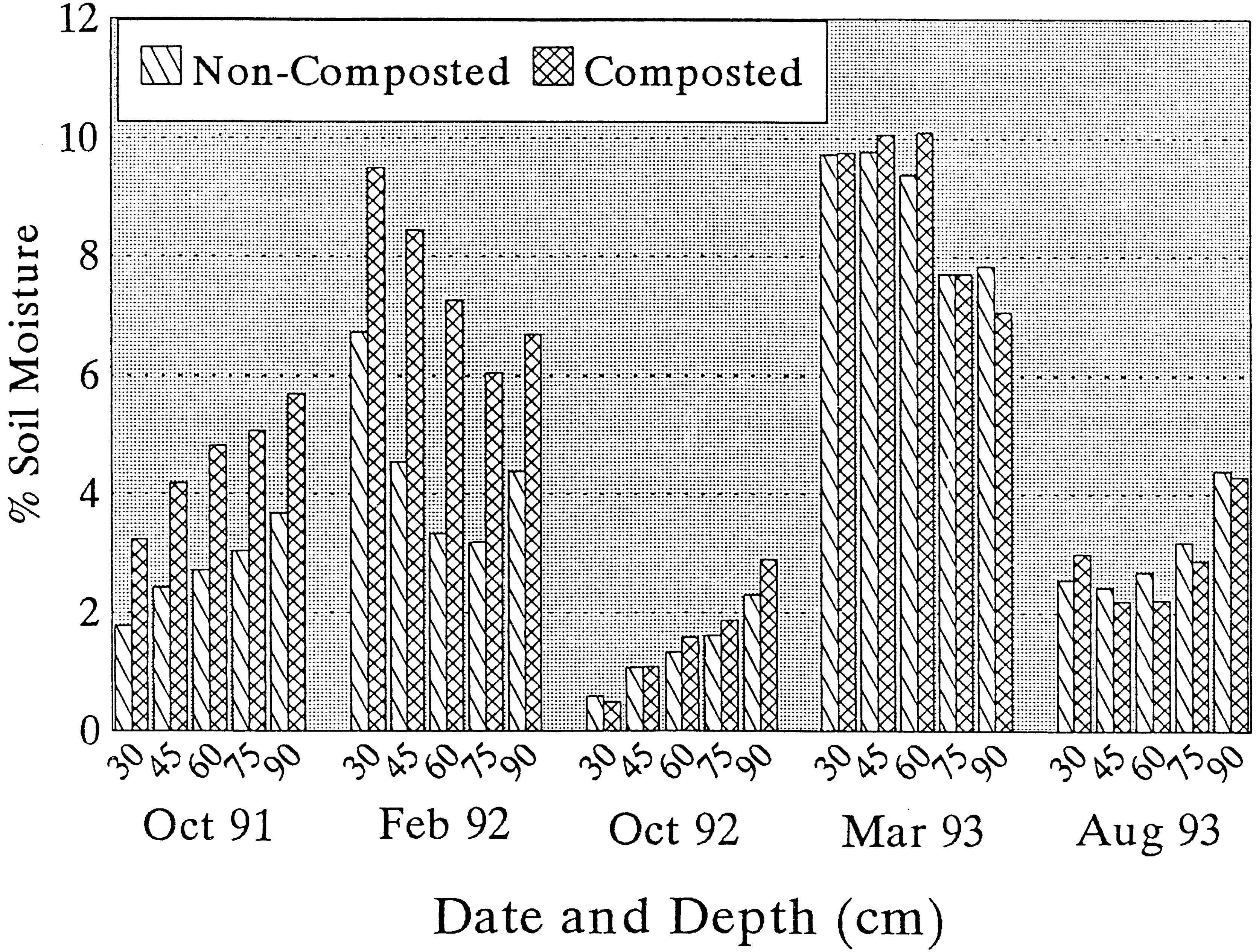


Figure 4-6. Compost Effects On Soil Moisture Storage.

composted plots are not significant on any of the last 3 sampling dates analyzed, at any of the depths.

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 lower 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.

5.0 PLANT COMMUNITY MEASUREMENTS

5.1 FIRST YEAR PLANT MEASUREMENTS

Measurements of the developing plant community were taken at two points during the 1992 growing season. Seedling density for both perennials and cheatgrass were determined in March, 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.

The plant density and coverage data were analyzed as a strip plot design with 6 replicates (blocks), 2 seed types, and 6 sealant/compost treatments. The complete analysis structure, including expected mean squares and critical F values is provided in Table 5-1. Within this model, the treatment effects can be further broken into the effects of compost, sealants, and the interactions among these. Treatment means were then compared using Duncan's Multiple Range test at a Type I error rate of 0.05.

The March seedling density values were determined by counting the number of seedlings within a 500 cm^2 (77.5 in^2) circle. Because different perennial grass species are difficult to differentiate at this stage, they were grouped into a single category, "Perennials." Three replicates within each plot/treatment subplot were collected by random placement of the quadrat frame. These three replicates were averaged to provide a mean value for each plot/surface/seed mix combination (i.e., 72 mean values in all). These means were then used in the subsequent data analysis. There were no significant differences in either the perennial or the cheatgrass density among the different surface treatments and seed mixes (Figures 5-1 and 5-2). A considerable amount of variation was encountered both among plots and among replicates within plots.

In June, 1992, 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*), Tumble mustard (*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 (5.4-ft^2) frame. The frequency for

Table 5-1. Analysis of Variance Structure for Plant Density and Coverage.

Source	Df	Code	EMS	Ftest	df/df	Fcrit
Replicates	5	R	$\sigma_e^2+12\sigma_R^2$	R/E	5/0*	NR*
Seed	1	S	$\sigma_e^2+6\sigma_{RS}^2+36\phi_s$	S/RS	1,5	6.61
Replicates x Seed	5	RS	$\sigma_e^2+6\sigma_{RS}^2$	RS/E	5,0*	NR*
Treatment	5	T	$\sigma_e^2+2\sigma_{TR}^2+12\phi_T$	T/TR	5/25	2.60
Treatment x Replicates	25	TR	$\sigma_e^2+2\sigma_{TR}^2$	TR/E	25/0*	NR*
Treatment x Seed	5	TS	$\sigma_e^2+\sigma_{TSR}^2+6\phi_{TS}$	TS/TSR	5/25	2.60
Treatment x Seed x Replicates	25	TSR	$\sigma_e^2+\sigma_{TSR}^2$	TSR/E	25/0*	NR*
Error	0	E	σ_e^2			
Total	71					

*F statistic is not retrievable.
EMS = expected mean squares.

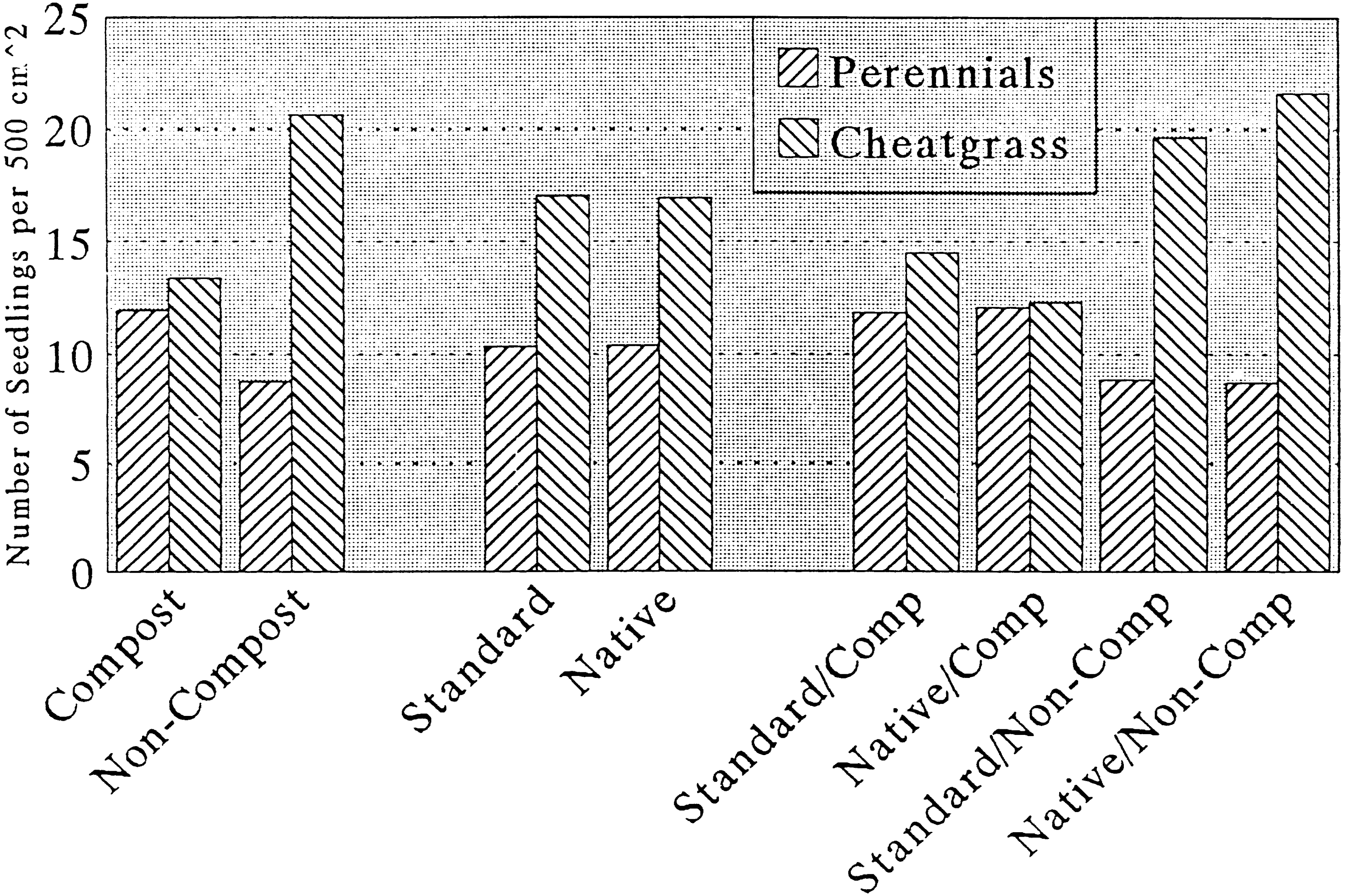


Figure 5-1. Seedling Density Compost and Seed Mix Effects (March 1992).

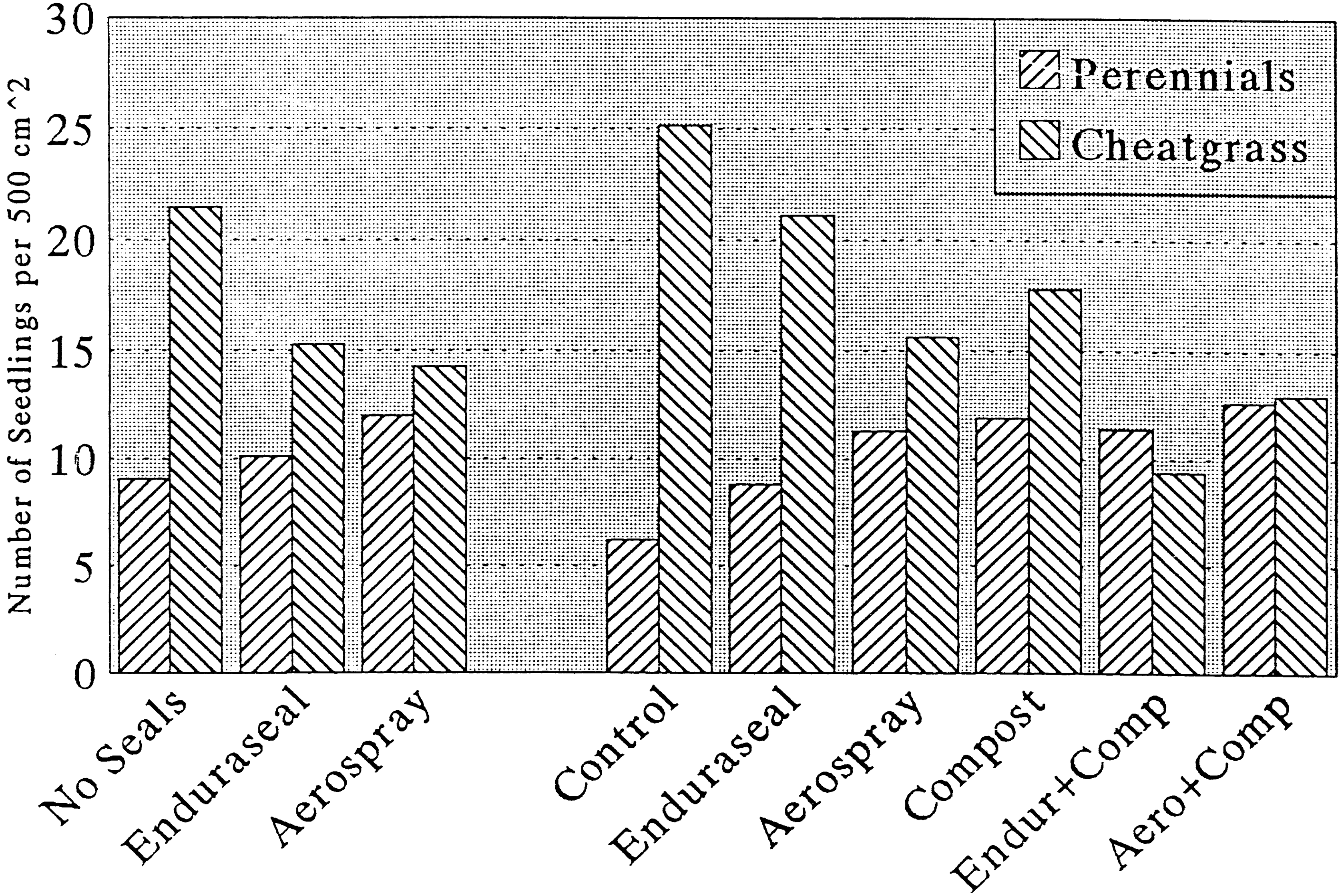


Figure 5-2. Seedling Density Soil Sealant Effects (March 1992).

cheatgrass was 100% and for weeds the frequency was almost 100%. Canopy coverage was determined by the proportion of predetermined points occupied by a particular species.

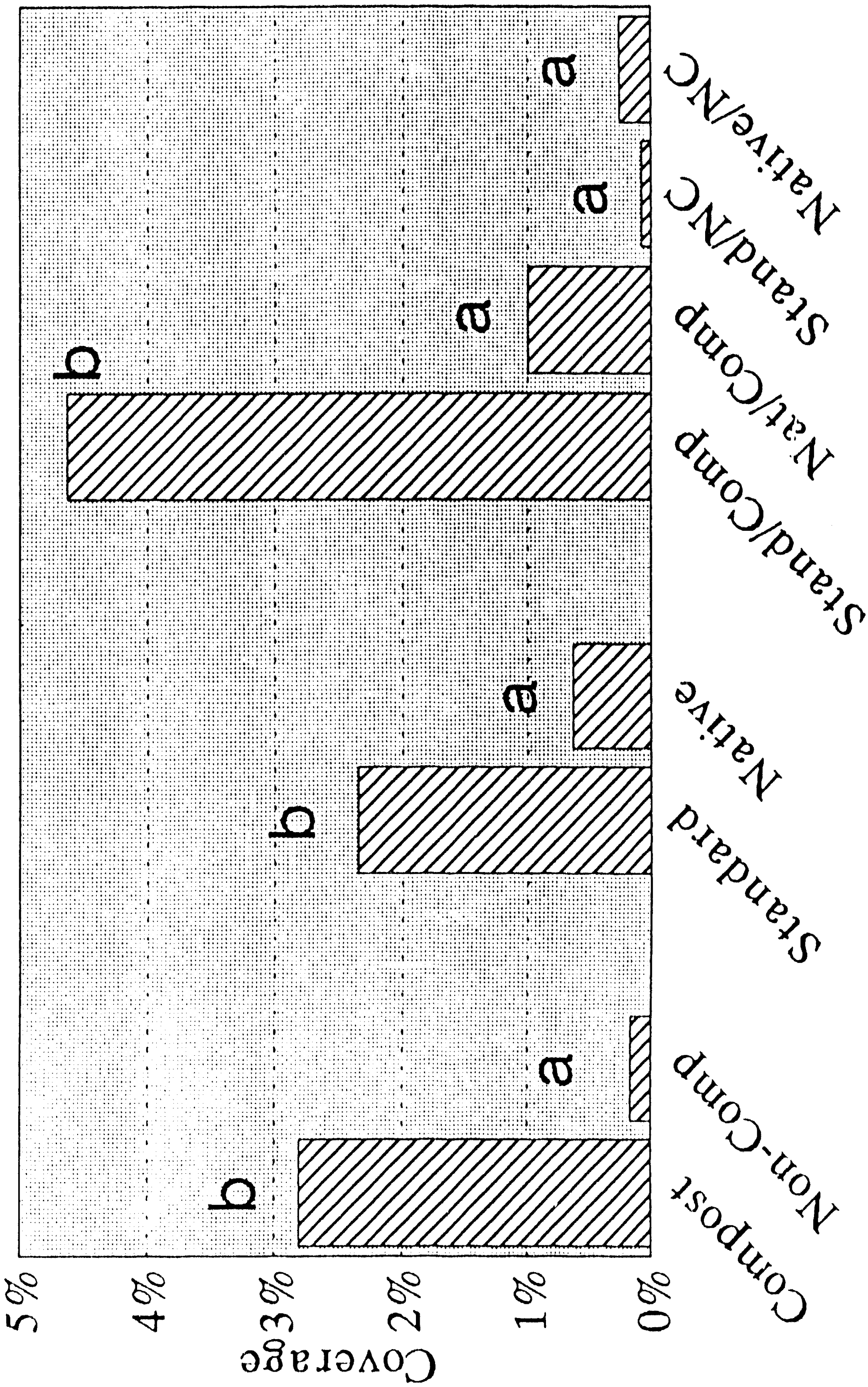
Both the perennial coverage and frequency were significantly higher in the plots with compost than in the plots without compost (Figures 5-3 and 5-4). The subplots planted with the standard wheatgrass mixture had higher perennial and significantly higher canopy coverage than the subplots planted with the native seed mix. Not surprisingly, the standard mix/compost subplots had significantly greater perennial canopy coverage and frequency than the other seed mix/compost combinations. The soil sealants in themselves did not significantly effect the perennial coverage or frequency (Figures 5-5 and 5-6). The perennial canopy coverage was higher in the plots that had both compost and Aerospray®-70, although most of this difference is probably attributable 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 (Figures 5-7 and 5-8). 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, slightly lower in the standard wheatgrass 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 assumed that the compost plots would of had much more cheatgrass than the noncomposted plots. Measurements of actual biomass production may have supported this contention better than the canopy coverage measurements.

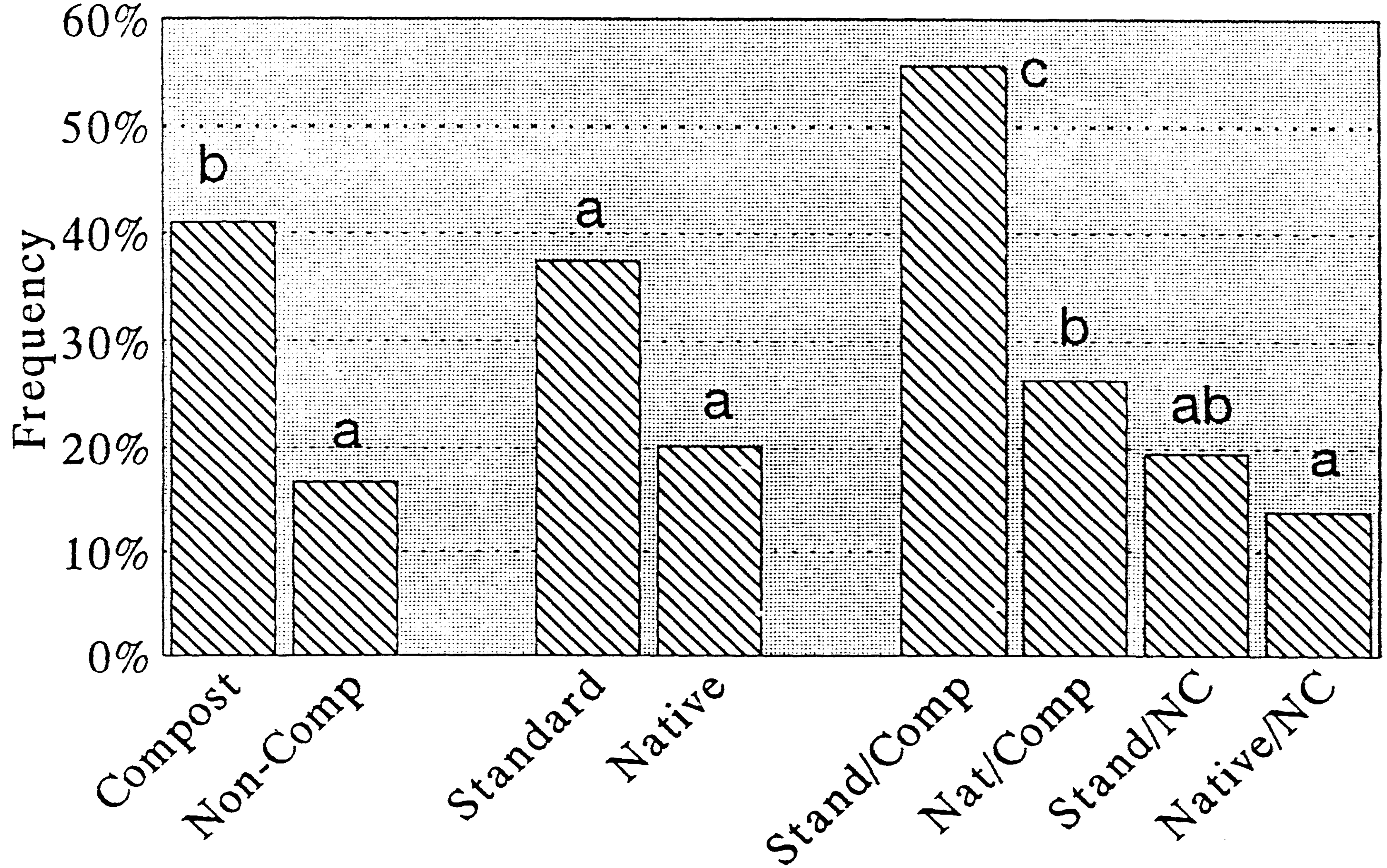
These initial plant community measurements indicate that compost has a distinct beneficial effect on the development of perennial grasses, whereas, the soil sealants do not appear to have had as much of an effect. Also cheatgrass appears to benefit from the presence of compost. At present, the standard wheatgrass mixture is performing better than the mixture of native grasses. This may be a result of more restrictive germination requirements of the native species relative to the wheatgrass species.

5.2 SECOND YEAR PLANT MEASUREMENTS

Because the survivorship of the perennial grasses into the second growing season was fairly low and sporadic, and 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 (8-in. by 20-in.) plot-frame, placed at 10 points within each of the 12 seed mix/surface treatment combination plots in all 6 of the whole plots. Total coverage within each plot-frame position was visually estimated and assigned a "coverage class" value between 0 and 6. Table 5-2 shows the ranges of coverage for each coverage class. After a coverage class was determined an estimate was made of the relative proportion of grass (cheatgrass plus perennials if present) and weeds in the coverage.

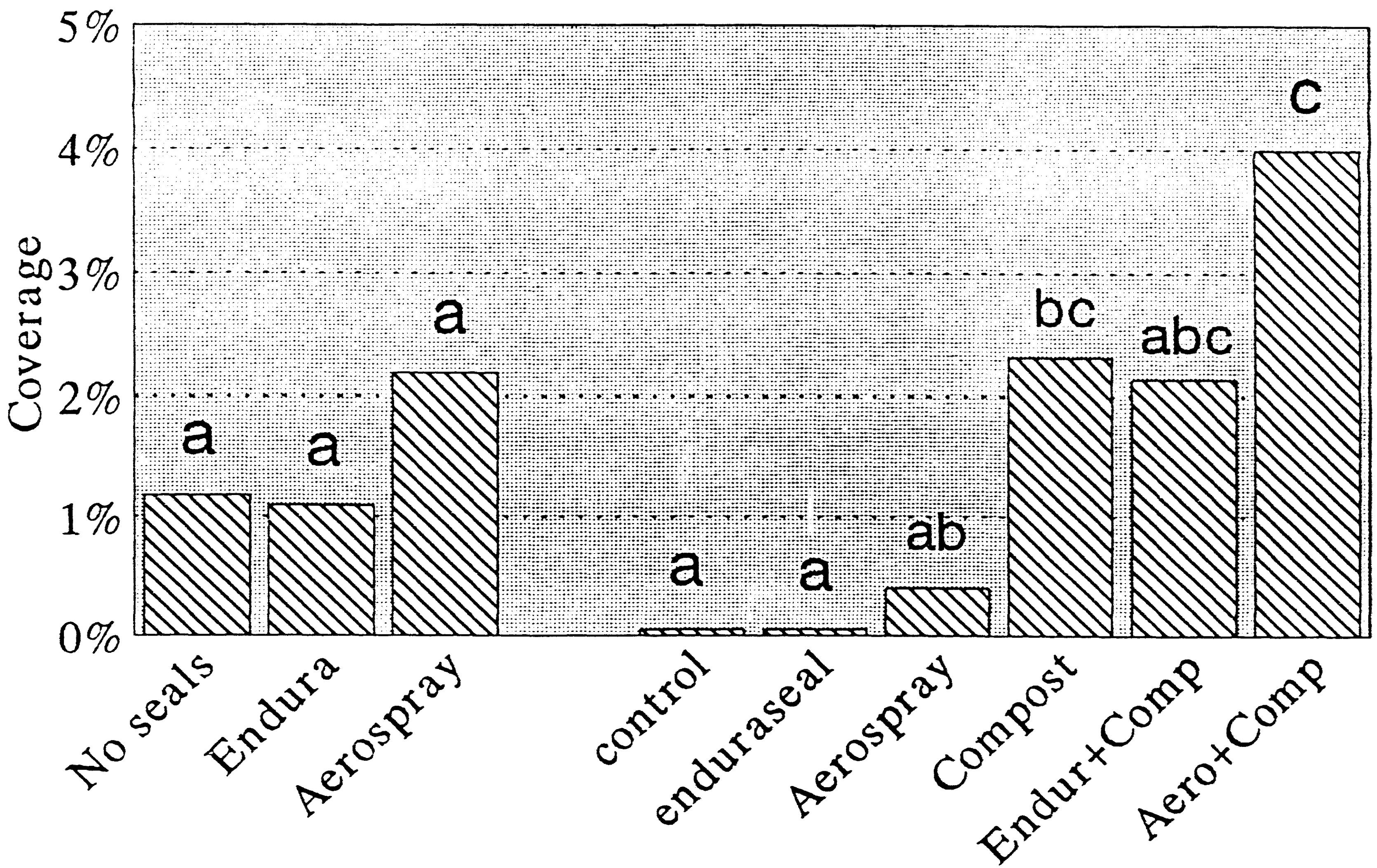
Figure 5-3. Perennial Coverage Compost and Seed Mix Effects (June 1992).





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

Figure 5-4. Perennial Frequency Compost and Seed Mix Effects (June 1992).



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

Figure 5-5. Perennial Coverage Soil Sealant Effects (June 1992).

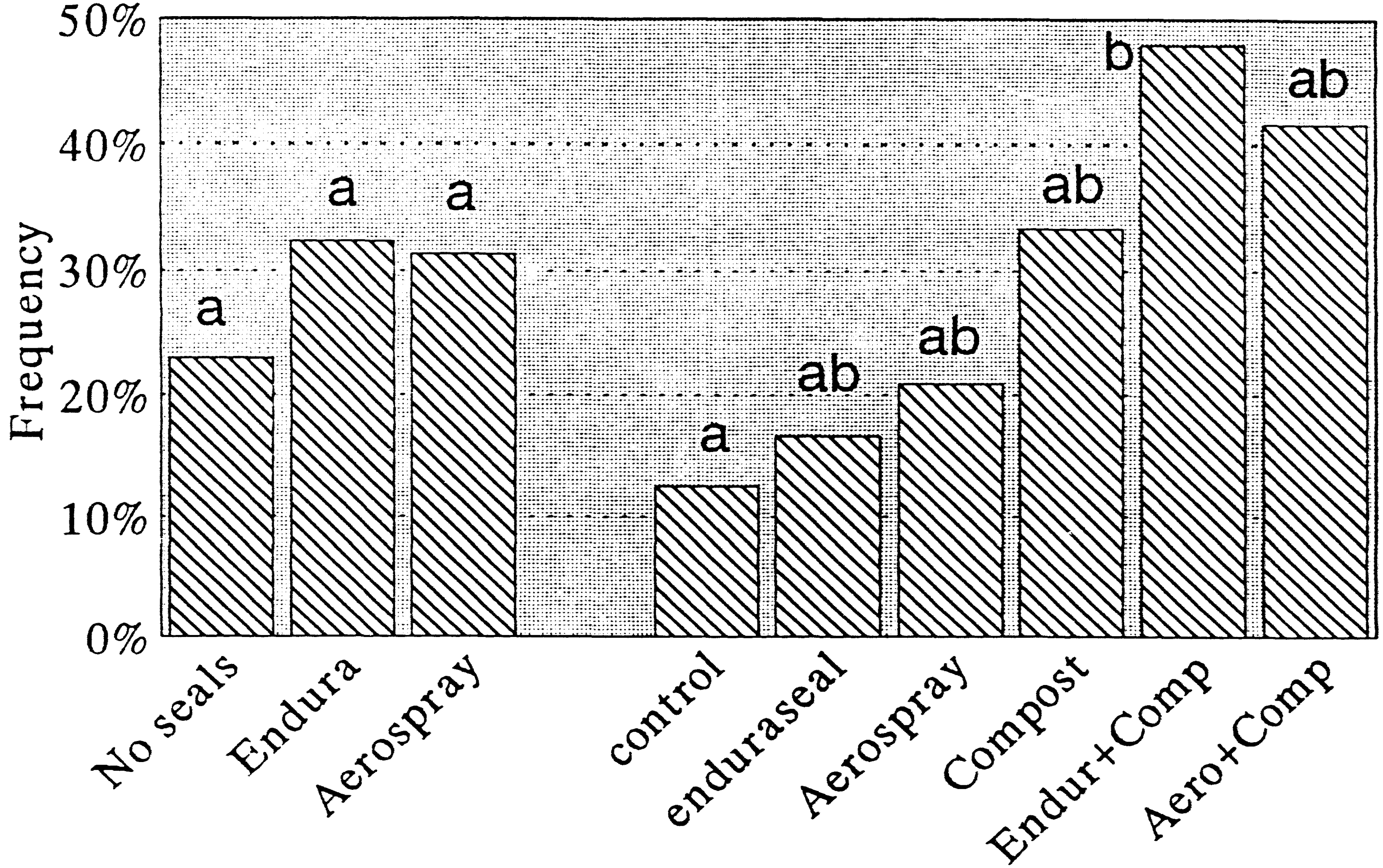
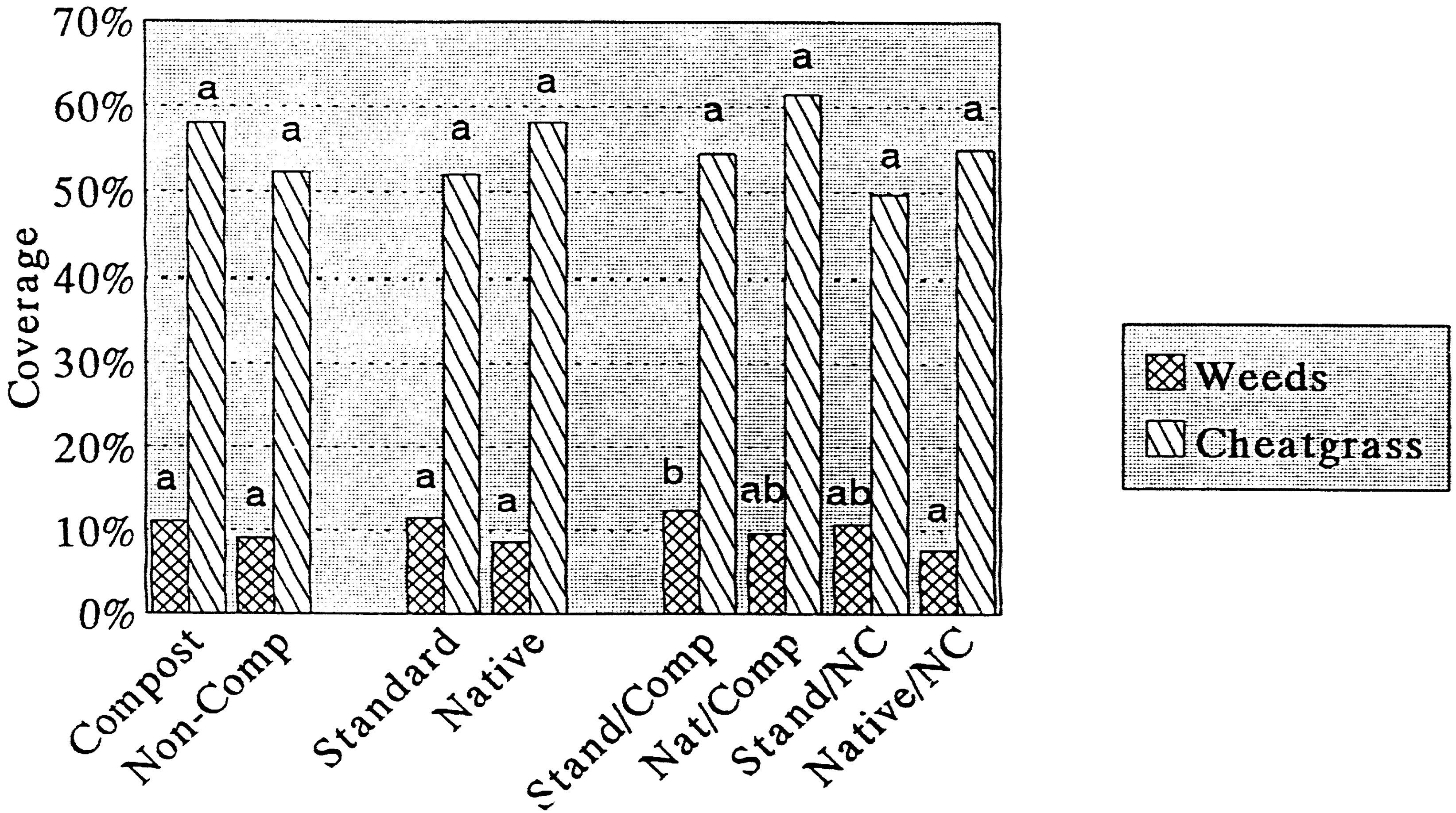


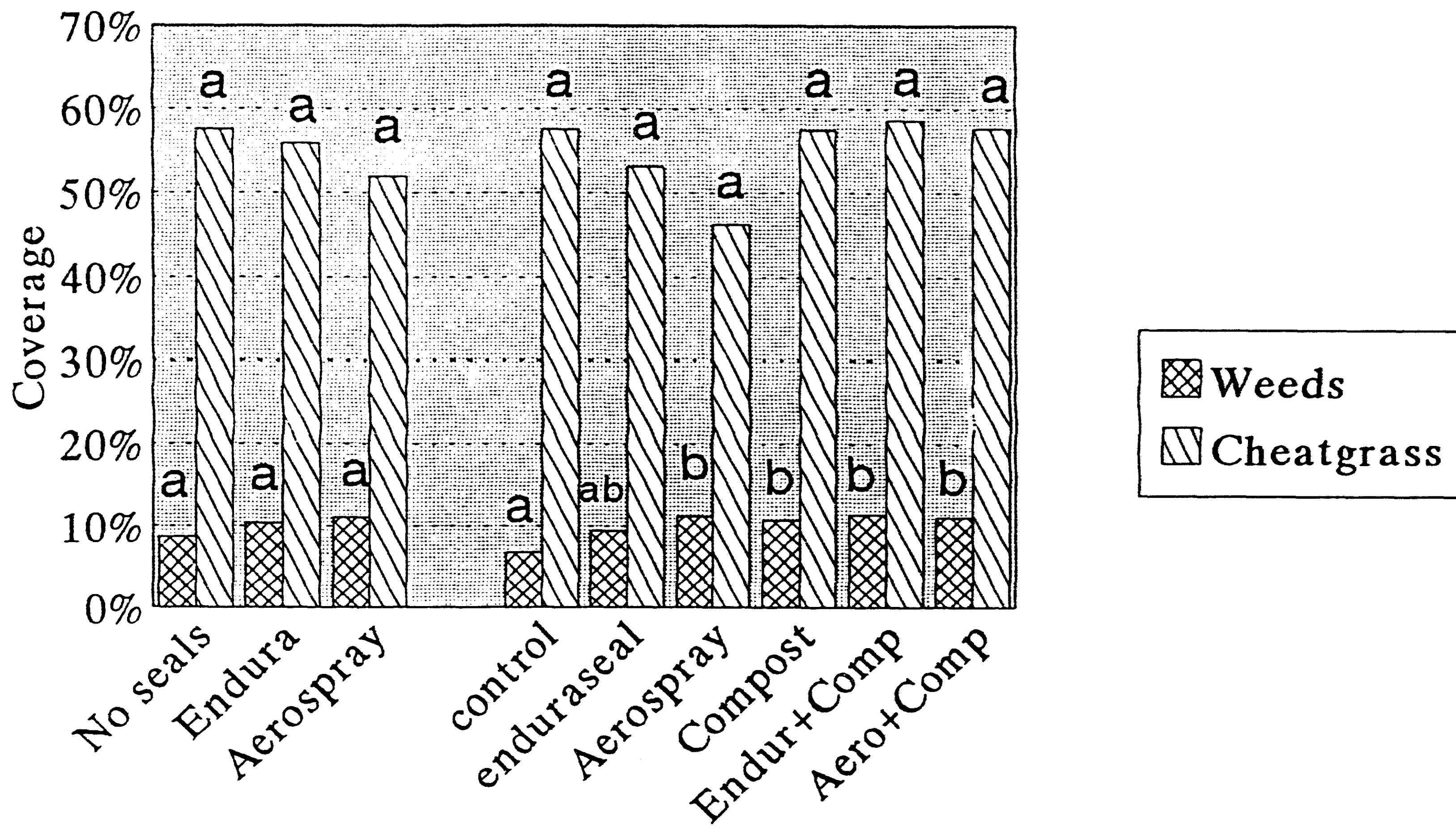
Figure 5-6. Perennial Frequency Soil Sealant Effects (June 1992).

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



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

Figure 5-7. Weed and Cheatgrass Coverage Compost and Seed Mix Effects (June 1992).



Bars for each species with in a grouping marked with the same letter are not significantly different at $p \leq 0.05$.

Figure 5-8. Weed and Cheatgrass Coverage Soil Sealant Effects (June 1992).

Table 5-2. Cover Class Ranges.

Cover Class	Range (%)
0	0
1	<5
2	5-25
3	25-50
4	50-75
5	75-90
6	>95

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. First, there were no noticeable differences among the plots seeded with the native grass mix or with the standard wheatgrass mix. Likewise, 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 slightly greater than 2. Figure 5-9 shows the average total plant coverage class for the 6 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%.

Total plant biomass production was estimated by collecting all of the vegetation within 3, randomly selected, 10-cm by 10-cm (4-in. by 4-in.) squares in each of the treatment plots. The plant material was then oven dried to a constant weight from which the dry weight was determined. The data was analyzed following the analysis of variance described in Section 5.1 and Table 5-1. For these analyses, the Tukey HSD multiple comparison procedure was used in place of the Duncan's Multiple range test used in the previous year to compare treatment means.

Figure 5-10 shows the relative effects of compost and initial seed mix on total plant biomass. It was found that compost has a highly significant effect on total plant biomass, while the initial seed mix does not, although the standard wheatgrass mix plots usually have slightly higher amounts of biomass. The lack of significant differences because of the initial seed mix is not surprising considering relatively low numbers of surviving perennials, and the preponderance of cheatgrass throughout the test site. Figure 5-11 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.

Figure 5-9. Total Plant Coverage Class.

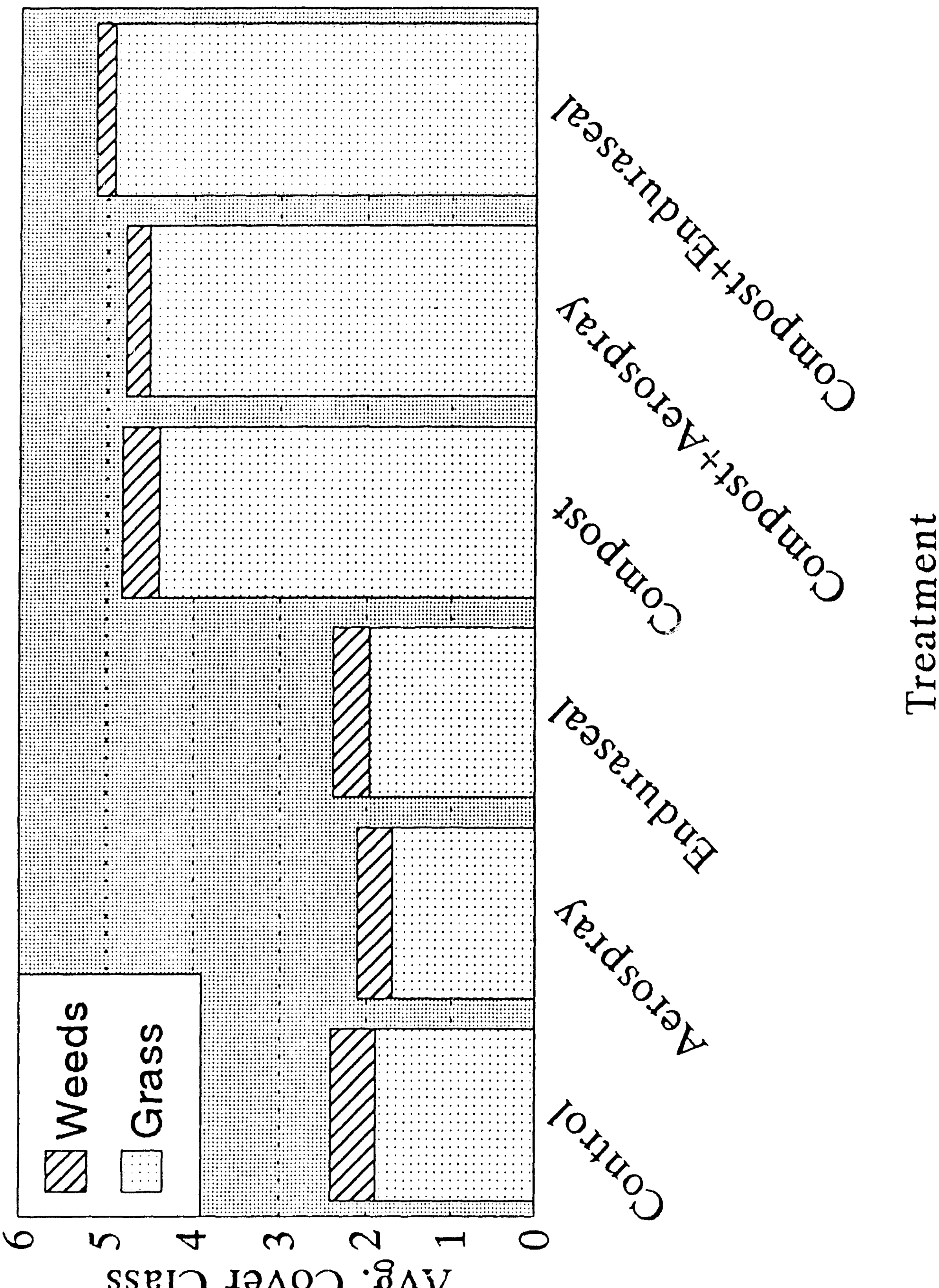


Figure 5-10. Total Plant Biomass Compost and Seed Mix Effects (June 1993).

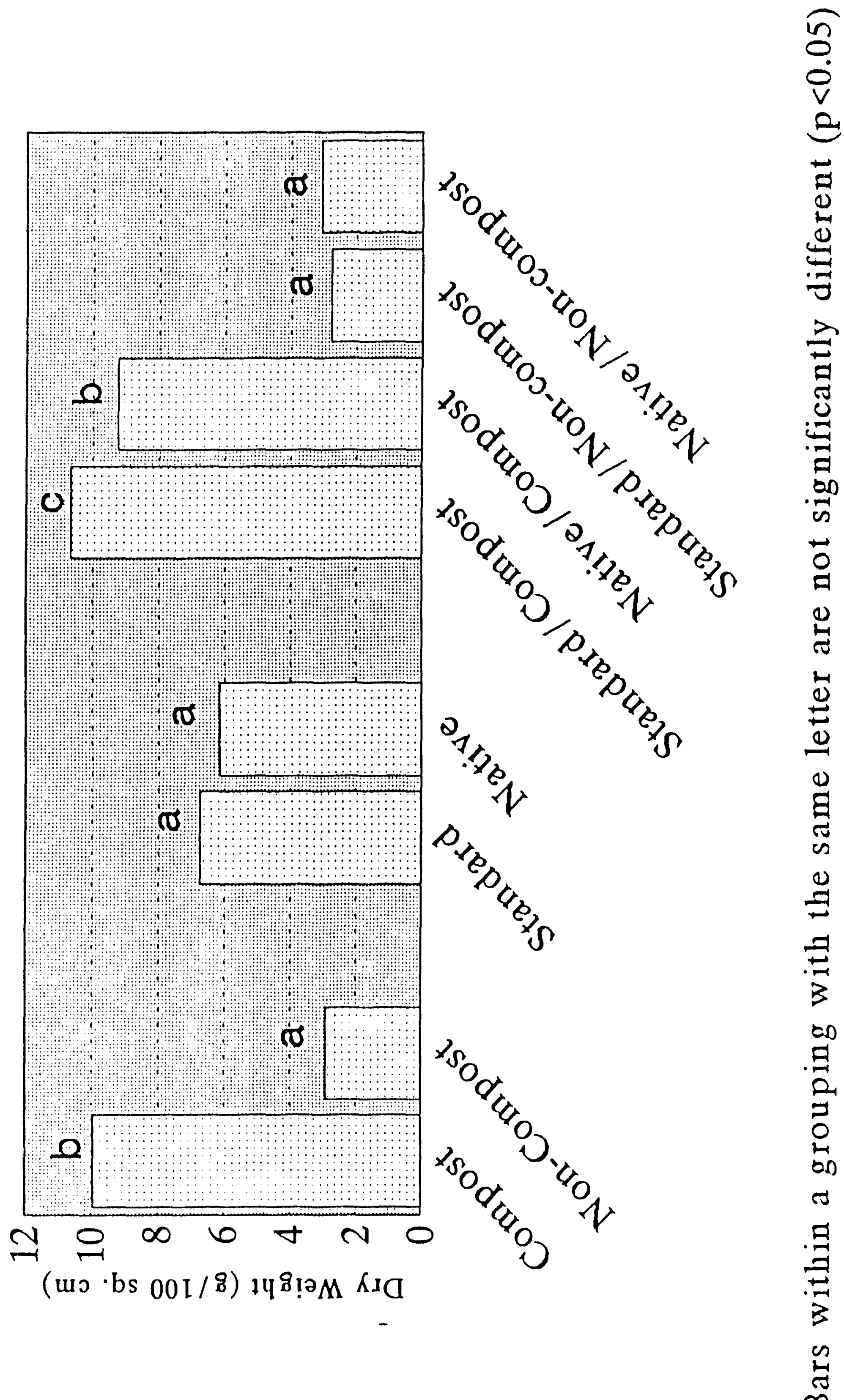
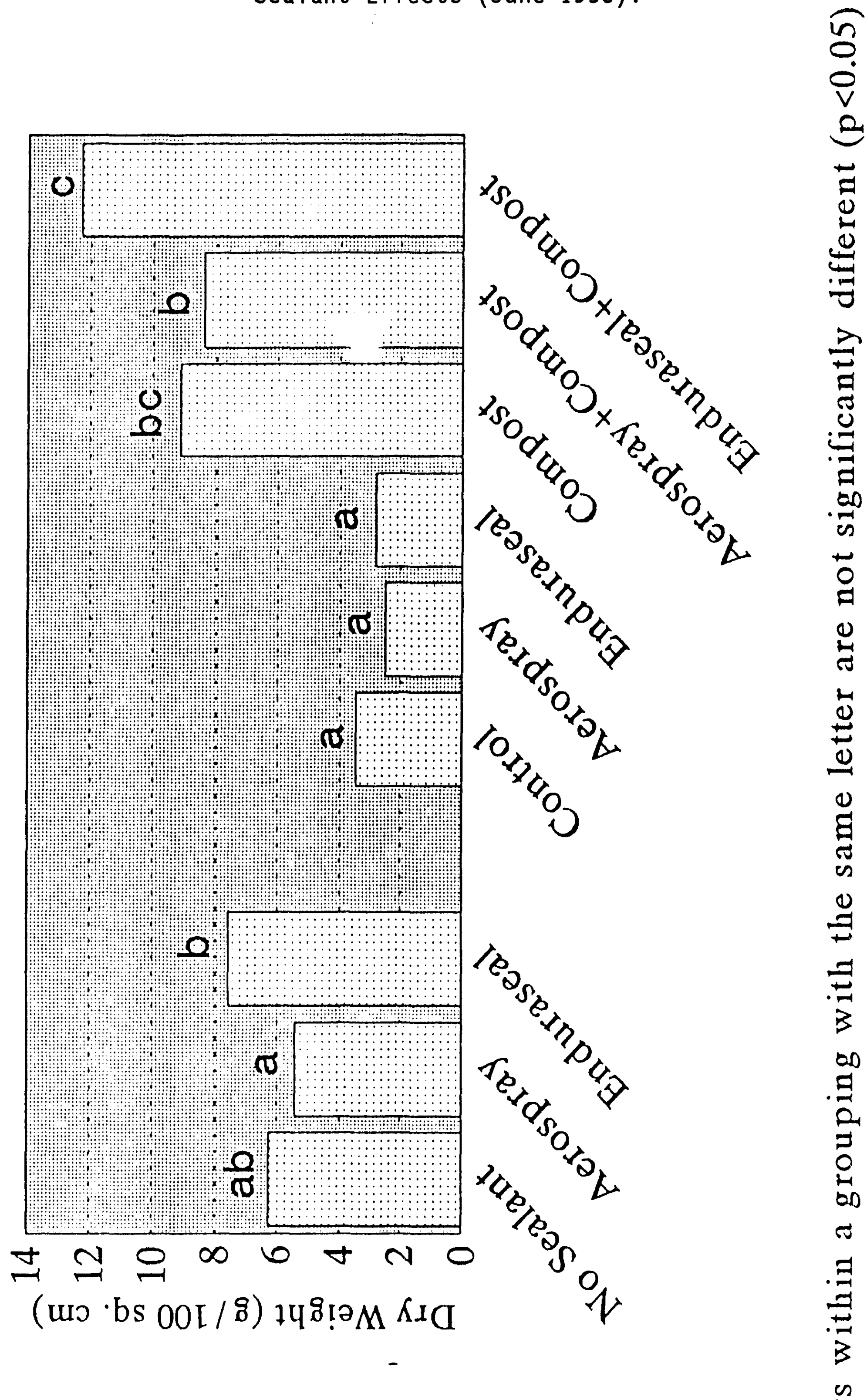


Figure 5-11. Total Plant Biomass Soil Sealant Effects (June 1993).



6.0 REFERENCES

ASTM, 1986, *Standard Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures*, ASTM D2216-86, American Society for Testing and Materials, Philadelphia, Pennsylvania.

Cox, G. R., December 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, L. L. Cadwell; 1993, *Status Report for the Small-Tube Lysimeter Facility Fiscal Year 1992*, WHC-EP-0597, Westinghouse Hanford Company, Richland, Washington.

WHC, 1990, *Environmental Technology Development and Applications Manual*, WHC-IP-0635, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

7.0 BIBLIOGRAPHY

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.

Tisdale, S. L., and W. L. Nelson; 1975; *Soil Fertility and Fertilizers*, 3 ed.; Chapters 5, 6, 7, and 8; McMillan Publishing Co. Inc., New York, New York.

Tucker, R. M., Revised by, 1985, *The LaMotte Soil Handbook*, LaMotte Chemical Products Company, pp 5 through 59, Chestertown, Maryland.

DISTRIBUTION

Number of Copies		
ONSITE		
1	U.S. Department of Energy, Richland Operations Office	
	Public Reading Room	H2-53
30	Westinghouse Hanford Company	
	J. W. Cammann	H4-14
	W. M. Hayward (5)	R2-77
	B. J. Hobbs	N3-06
	M. C. Hughes	R2-81
	C. J. Kemp (5)	H4-14
	M. K. Korenko	B3-08
	C. L. Looney	N3-06
	M. B. Malady	N3-06
	M. A. Mihalic	R2-77
	R. W. Powell	H4-14
	M. R. Sackschewsky (5)	H4-14
	D. L. Smith	R2-77
	J. C. Sonnichsen	H4-14
	Central Files	L8-04
	Information Release Administration (3)	A3-36
	Publication Services	A2-25

DATE
FILMED
11/23/93

END