EG&G Energy Measurements
Environmental Sciences Department

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EFFECTS OF GRAVEL MULCH ON EMERGENCE OF GALLETA GRASS SEEDLINGS

Oral Summary Report

DISCLAIMER

March 1993

INTRODUCTION

The Department of Energy Nevada Operations Office (DOE/NV), Technology Development and Program Management Division, has identified the need to clean up several sites on the Nevada Test Site (NTS) and Tonopah Test Range (TTR) contaminated with surface plutonium. An important objective of the project identified as the Plutonium In Soils Integrated Demonstration (PuID) is to develop technologies to stabilize and restore the disturbed sites after decontamination. Revegetation of these contaminated sites will be difficult due to their location in the arid Mojave and Great Basin Deserts. The major factors which will affect successful plant establishment and growth at these sites are limited and sporadic precipitation, limited soil water, extreme air and soil temperatures, limited topsoil, and herbivory by rabbits and wild horses.

Nearly all plutonium at the contaminated sites is limited to the top 10 cm of soil, and is associated with the <3 mm soil fraction. The >3 mm (gravel) fraction may be separated by sieving during the plutonium removal process, and then stockpiled, or reused during site restoration and stabilization activities. This material could be deposited on top of replaced soil to act as a mulch to stabilize the soil and conserve soil water.

Mulches aid plant establishment by providing microsites for seeds which enhance soil water and temperature conditions, and stabilize erosive soils (Kay 1978). Plant litter can be thought of as a natural mulch in that it can provide microsites for seeds. Evans and Young (1970, 1972) reported greater emergence of downey brome (*Bromus tectorum* L.), medusahead rye (*Taeniatherum asperum* Simonkai) Nevski), and Russian thistle (*Salsola iberica* L.) from seeds under plant litter than from seeds on the bare soil surface. Environmental monitoring showed that plant litter greatly moderated maximum and minimum soil temperatures, decreased the amount of light reaching the soil surface, and greatly increased relative humidity. Rocks and gravel can also provide natural microsites for seed. Fowler (1986) observed that *Bouteloua rigidiseta* and *Aristida longiseta* germinated, survived, and grew better under rocks and plant litter than on the bare soil surface. In a greenhouse study, emergence of 'Vaughn' sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), 'A-130' blue panic (*Panicum antidotale* Ritz.), and 'Cochise' Antherstone lovegrass (*Eragrostis lehmanniana* Nees x *E. tricophera* Coss and Dur.) was highest from a gravel mulch treatment (Winkel et al. 1991). An analysis of soil water content for each of the treatments in the study indicated that soil water decreased faster in a bare soil surface treatment than in a gravel mulch treatment.

Research has shown that providing microsites for seed via mulching can aid in plant emergence and establishment. Since many of the soils at the sites slated for plutonium decontamination have a large percentage of gravel in the upper 10 cm of soil, the use of gravel as mulch could provide microsites for seed and stabilize soils during subsequent revegetation of the sites. In July, 1992, EG&G/EM Environmental Sciences Department initiated a greenhouse study to examine the possible benefits of gravel mulch. The specific objectives of this greenhouse study were to: 1) determine the effects seedling emergence and soil water, and 2) determine effects of irrigation rates on seedling emergence for gravel mulches and other conventional seedbed preparation techniques. A secondary objective was to determine the depth of gravel mulch that was optimal for seedling emergence. Results from this greenhouse study will assist in formulating specific reclamation plans for sites chosen for cleanup.

METHODS

The study was conducted in an evaporative-cooled greenhouse in Mercury on the NTS from July 15 to August 4, 1992. Daily maximum and minimum air temperatures inside the greenhouse during the study ranged from 26.6 to 35.2 °C, and 13.8 to 19.4 °C, respectively.

Soil from the top 15 cm was collected from Area 11, sieved to 3 mm and the <3-mm fraction was placed in 40x60x10-cm flats. Each flat was then seeded with 20 seeds each of the following nine species: fourwing saltbush (*Atriplex canescens*), threadleaf rubber rabbitbrush (*Chrysothamnus nauseosus consimilis*), basin big sagebrush (*Artemisia tridentata tridentata*), galleta grass (*Hilaria jamesii*), Indian ricegrass (*Oryzopsis hymenoides*), alkali sacaton (*Sporobolis airoides*), desert mallow (*Sphaeralcea ambigua*), Palmer penstemon (*Penstemon palmeri*), and spiney hopsage (*Grayia spinosa*).

The seeds of these nine species were planted in the flats several different ways to simulate conventional seedbed treatments that may be used in the field. For the "bare" treatment, seeds of all species were broadcasted on the bare soil surface with no further treatment. For the "buried" treatment, seeds of all species were broadcasted and then covered with a 1-cm layer of soil. The "buried" treatment was selected to simulate the placement of seeds with a seed drill which is a standard method of placing seeds at precise depths in the seedbed. The "2-cm gravel" and "4-cm gravel" treatments consisted of broadcasting seeds on the soil surface, and then covering the seeds with a 2-3 or 4-5-cm layer of gravel. Gravel was obtained from Area 11 soil material. The two gravel treatments were selected using the rationale that approximately half of the soil material in Area 11 is gravel (particles >3mm). For example, if 5 cm of contaminated soil material were removed for processing, enough gravel to form a 2-3 cm layer would be available as a mulch. If 10 cm of contaminated soil material were removed, gravel for a 4-5 cm layer would be available. More than 5 cm of Area 11 gravel would probably severely inhibit seedling emergence, therefore 5 cm was considered the greatest depth of gravel necessary to test.

Three irrigation treatments were selected to simulate the wide variety of soil water conditions that may occur in the Mojave Desert of southern Nevada, and to test a range of irrigation rates. The irrigation treatments included: 1) watering on day one only, 2) watering on day one and every fifth day thereafter, and 3) watering on day one and every tenth day thereafter. Flats were watered to saturation by sprinkling on each watering day, and allowed to freely drain.

Seedling emergence data (number of emerged seedlings of each species/flat) was collected daily. Seedling emergence criteria for each seedbed treatment were as follows: 1) bare treatment: seedlings > 5 mm tall with radicles penetrating the soil surface; 2) buried treatment: seedlings emerged from soil surface; 3) 2-cm and 4-cm gravel: seedlings above the gravel surface. Percent seed germination of each species was determined in the greenhouse with two replications of each species using the petri dish technique. For each replication, 100 seeds were placed on filter paper in a petri dish. Seeds were watered on day one and whenever necessary throughout the study to maintain optimal conditions for germination. Germination counts were conducted every 24 $\pm$ 2 hours after initial watering. A seed was considered germinated when its radicle had emerged.

To determine why seeds and seedlings responded as they did to the seedbed treatments with respect to soil water, gravimetric soil water content was measured from samples obtained from additional non-seeded flats. These flats were filled with soil, treated with the seedbed treatments (without the seeds), and irrigated as above. Beginning on day one and continuing daily throughout the study (with the exception of days four and 14), approximately 10 cm^3 of soil from each of the non-seeded flats was collected. The specific depth from which soil samples were collected for each treatment was as follows: 1) bare treatment: the top 5 mm of soil; 2) buried treatment: 5 to 15 mm beneath the soil surface; 3) 2 and 4-cm gravel treatments: the top 5 mm of soil under the gravel. Soil sampling depths differed by treatment because of the need to sample soil adjacent to the seed. This allowed measurement of soil water at the soil-seed interface, which is critical to determine microsite effects. Gravimetric soil water content of the samples was determined by weighing before and after oven-drying (Hillel 1982), and is expressed as a percent.

Soils data from several other sites on the NTS having soils similar in texture to that used in this study were used to estimate percent water content at -0.03 and -1.50 MPa (megapascal) matric potentials. These numbers, -0.03 and -1.50 MPa, refer to the "field capacity" and "permanent wilting point" of the soil, respectively. Field capacity is that point at which all free water has drained from the soil and maximum water is available for plant growth. Permanent wilting point is that point at which soil water is no longer available to many species of plants and desiccation occurs. Matric potential data is useful in relating soil water content data to plant response.

The experimental design was a split plot with two blocks (replications). Whole plot variables were irrigation and gravel treatments, and species; days was the split plot variable. All factors were assumed fixed. Each irrigation treatment / gravel treatment / species combination was randomized within blocks. The study included 24 seeded and non-seeded flats (n=2), with each block containing 12 each of seeded and non-seeded flats (4 gravel treatments x 3 irrigation treatments).

Analysis of variance was performed on seedling emergence data, and on the arcsin square root of percentage data (Sokal and Rohlf 1981) for soil water content data using the SAS GLM procedure (SAS 1989). Significant means were separated with Fisher's Least Significant Difference test.

RESULTS AND DISCUSSION

Seedling Emergence

Seedling germination tests in petri dishes were implemented at the same time as seedbed/irrigation treatments in order to expose the germination tests to the same environmental conditions as that of the seedbed/irrigation treatments. Unexpectedly, only galleta grass had high germination in the petri dishes (Figure 1) and sufficient response in the seedbed/irrigation treatments. The other eight species had germination below 50% which was considered to be the minimum germination to allow statistical comparisons in the seedbed/irrigation treatments. Because of the lack of germination exhibited by these eight species, they will not be included in the discussion of seedbed/irrigation treatment effects.

Because only galleta grass had sufficient germination to allow statistical comparisons of seedbed/irrigation treatments, the statistical design was modified. Whole plots variables were irrigation and gravel treatments; days were split plot variables. Species was dropped as a whole plot factor. Analysis of variance of seedling density data showed significant ($p<0.05$) two- and three-factor interactions involving irrigation treatments, gravel treatments, and days.

When watering occurred on day one only, similar numbers of galleta grass seedlings emerged from the buried and 2-cm gravel treatments (Figure 2). In contrast, few seedlings emerged from the bare treatment, and no seedlings emerged from the 4-cm gravel treatment. The few seedlings that did emerge from the bare treatment succumbed to desiccation by the end of the study. A portion of seedlings that emerged from the buried treatment died from desiccation on day 15, and over one-half had died by the end of the study. In comparison, all seedlings emerging from 2-cm gravel survived until the end of the study.

When watering occurred every ten days, seedlings emerged from and survived in the 2-cm gravel and buried treatments equally well (Figure 3). Again, few seedlings emerged from the bare treatment. A small number of seedlings emerged from the 4-cm gravel but these were not statistically significant from the bare treatment.

When watering occurred every five days, galleta grass seedlings emerged and survived best from the 2-cm gravel treatment (Figure 4). Although the buried treatment produced nearly as many seedlings as did the 2-cm gravel treatment, some of the seedlings died after 15 days. No seedlings emerged from the 4-cm gravel treatment. Seeds from the bare treatment responded well to watering every five days and survived until the end of the study.

Soil Water

The analysis of variance for soil water data showed significant ($p < 0.05$) two- and three-factor interactions involving irrigation treatments, gravel treatments, and days. When irrigation occurred on day one only, soil water content remained above a corresponding matric potential of -1.50 MPa until day five in the buried and bare treatments, and until day 10 and 22 in the 2-cm gravel and 4-cm gravel treatments, respectively (Figure 5). Again, this may help to explain why seedlings responded better to the 2-cm gravel. The 4-cm gravel treatment conserved soil water twice as well as the 2-cm gravel, and four times as well as the bare and buried treatments. Few seedlings, however, emerged from the 4-cm gravel treatment. The thickness of the gravel layer may have been prohibitive to the emergence of seedlings. Seedlings under the 4-cm gravel layer were inspected at the end of the study. Although many seeds germinated, most of the seedlings were etiolated (lacking chlorophyll) and growing horizontally. Some had been infested by fungi which may indicate that conditions under the 4 to 5-cm gravel layer may have been too wet for optimal plant growth, particularly when watering occurred every five days.

When irrigation occurred every ten days, water content of soil under either 2 or 4-cm of gravel stayed above a corresponding matric potential of -1.50 MPa throughout the study. Water content of soil from the bare and buried treatments, however, dropped below a corresponding matric potential of -1.50 MPa after 3-4 days and remained below that level for up to seven days. When irrigation occurred every five days, the water content of soil under the two gravel treatments remained above a corresponding matric potential of -0.03 MPa throughout the study (Figure 5). In contrast, soils without gravel mulch dried to a corresponding matric potential below -1.50 MPa within 3 days after every irrigation. This may help explain why seedlings responded so favorably to the 2-cm gravel treatment, and why seedlings from the other treatments either failed to emerge, or failed to survive until the end of the study.

Seedlings emerged from the bare treatment that was watered every five days. Apparently this irrigation treatment kept the soil moist long enough for germination to occur. This treatment shows that frequent moisture replenishment is critical for germination of broadcast seed.

CONCLUSIONS

This study showed that under a variety of soil water conditions, a 2-3 cm gravel layer may aid emergence of galleta grass. Results from this study also demonstrated that a deeper layer of gravel (4 - 5 cm) prohibits emergence, probably because it acts as a physical barrier to the seedlings. Galleta grass emergence can be used as a model for how other species might respond to these seedbed and irrigation treatments, provided they have adequate germination and are exposed to similar environmental conditions.

This study was conducted with native soils at temperatures similar to those found during the summer in the Mojave desert. However, due to the fact that it was conducted in small flats in a greenhouse, care should be taken when trying to extrapolate the results to actual field conditions. Further studies should be conducted in the field under natural conditions before a gravel mulch treatment is selected for implementation in a revegetation program. Further greenhouse studies should be conducted under differing environmental regimes and with other native species. Such studies could help determine if species' response to gravel mulch treatments vary seasonally and if gravel mulching is appropriate for many of the native species to be used in reclamation of the decontaminated sites.

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Effects of Gravel Mulch On Emergence of Galleta Grass Seedlings

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Objectives

- Determine effects of gravel mulch on seedling emergence and soil water.
- Determine effects of irrigation rates on seedling emergence for gravel mulches and other conventional seedbed preparation techniques.
- Determine optimal depths of gravel mulch.

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Methods

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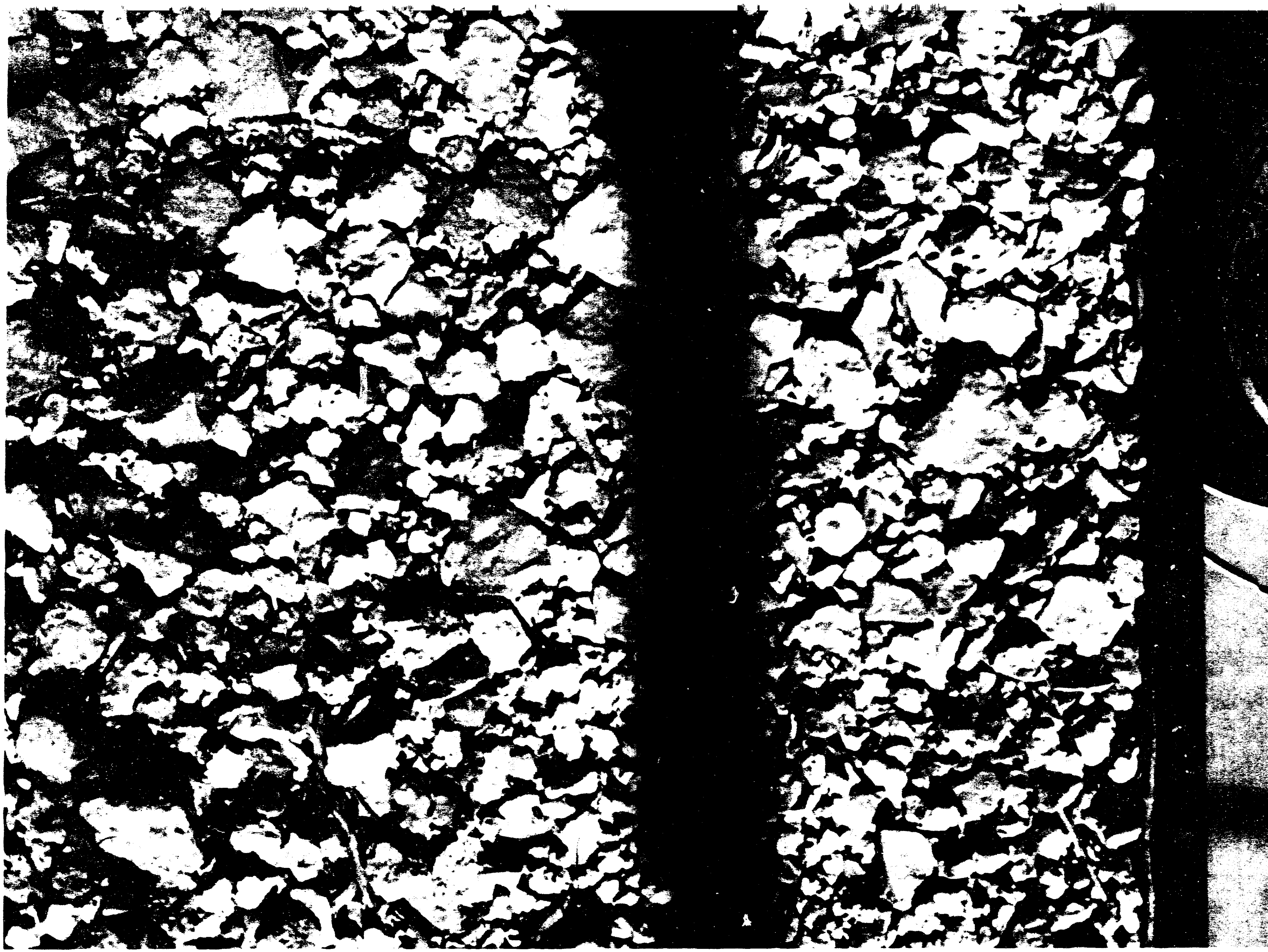

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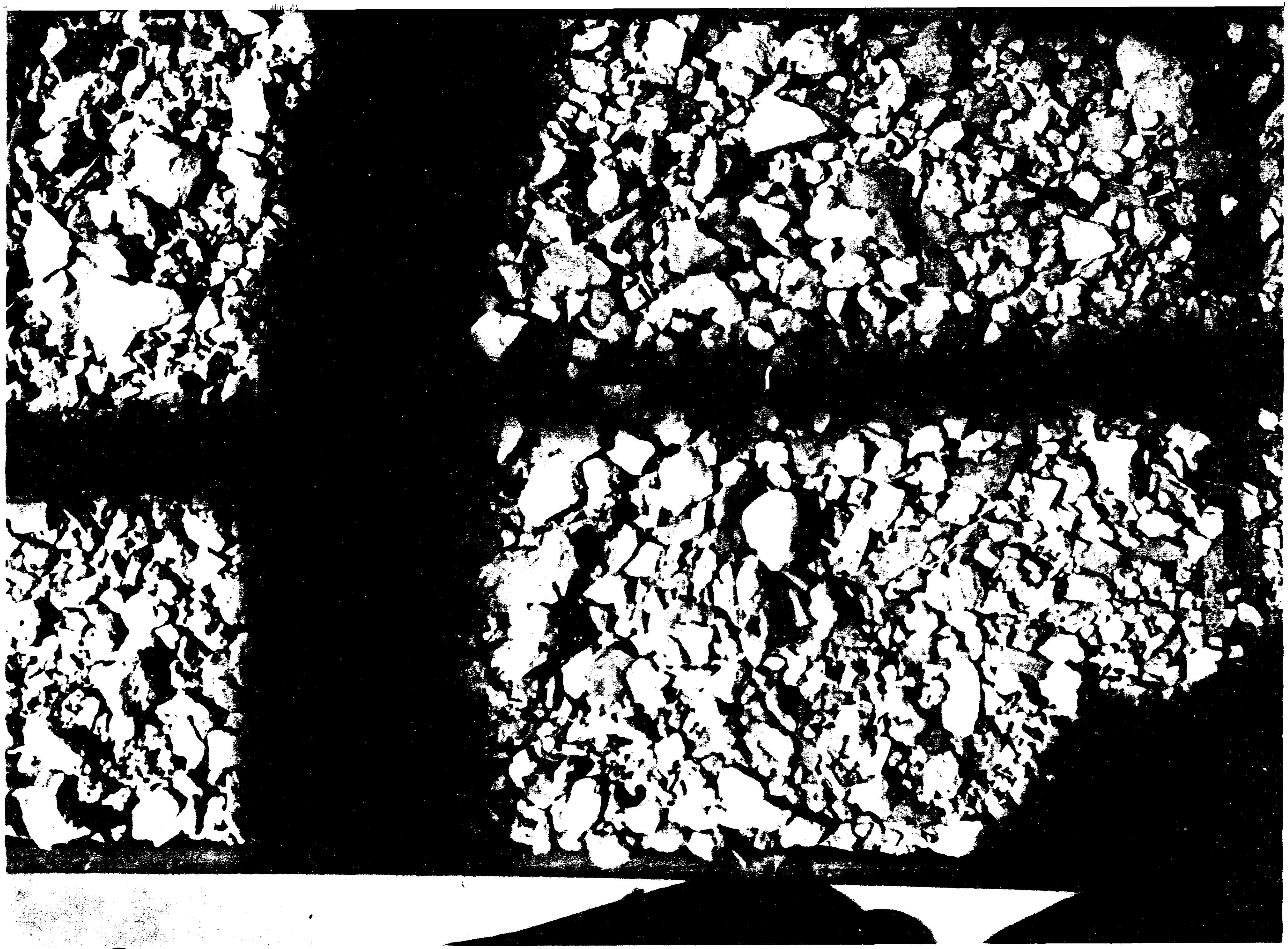

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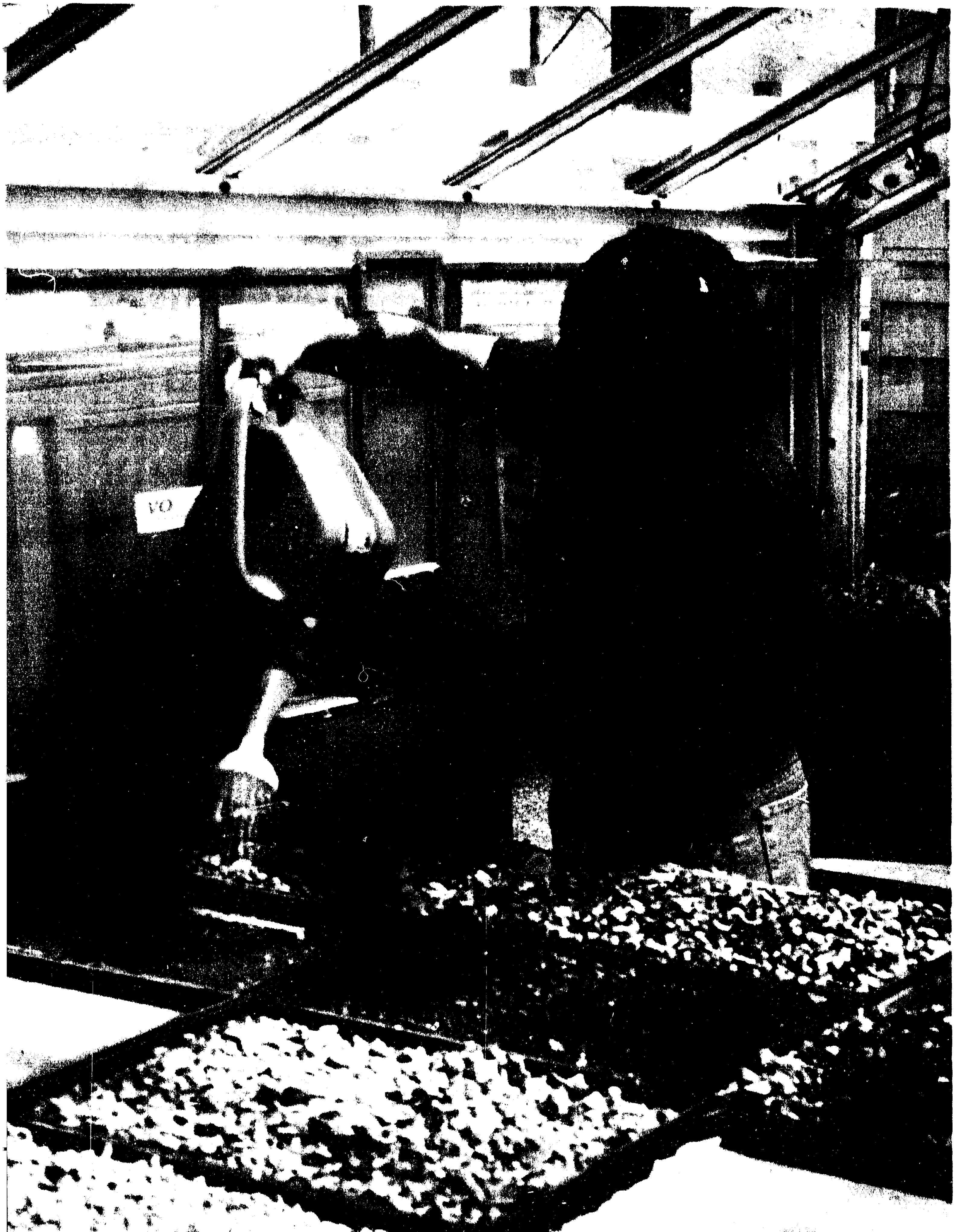
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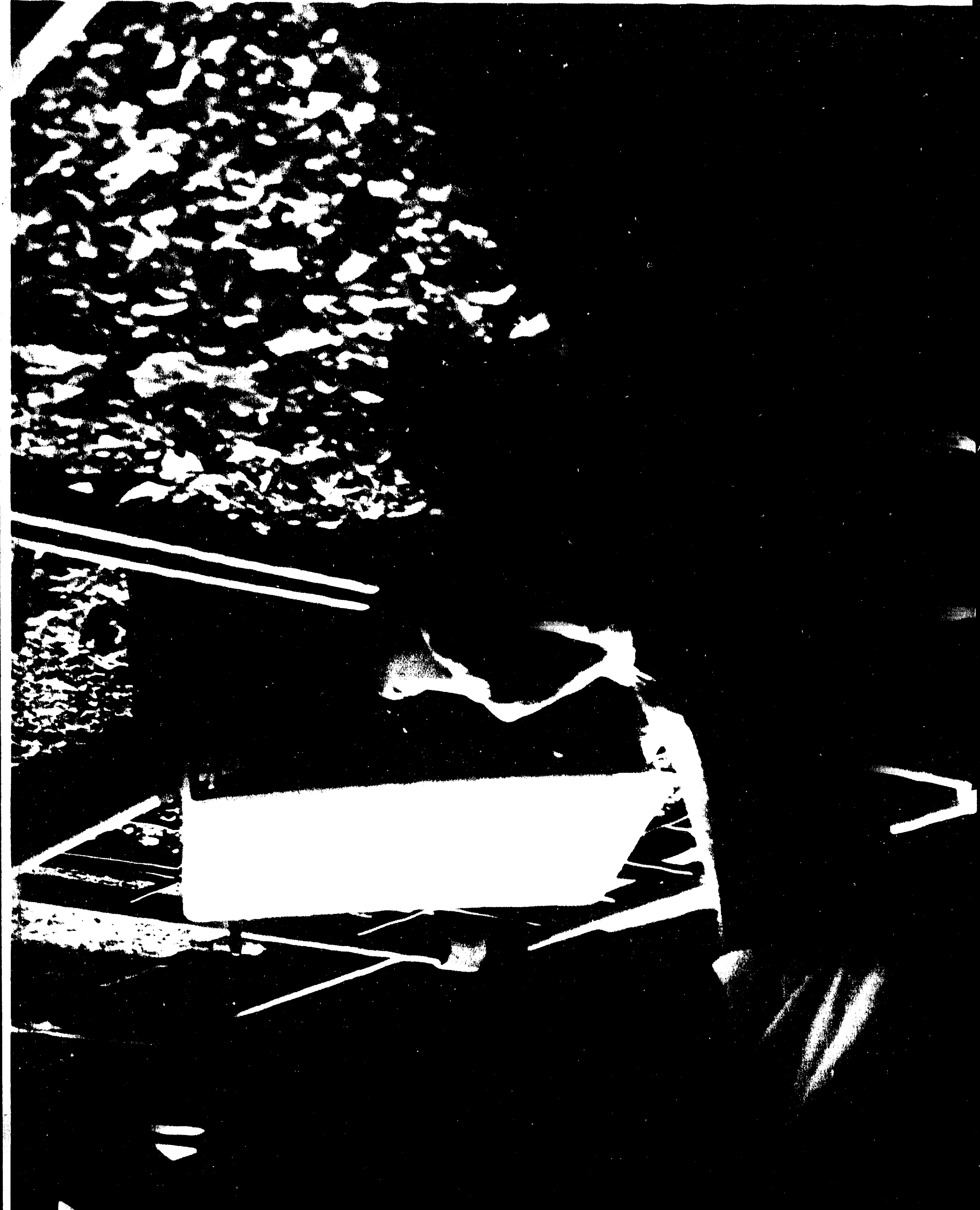

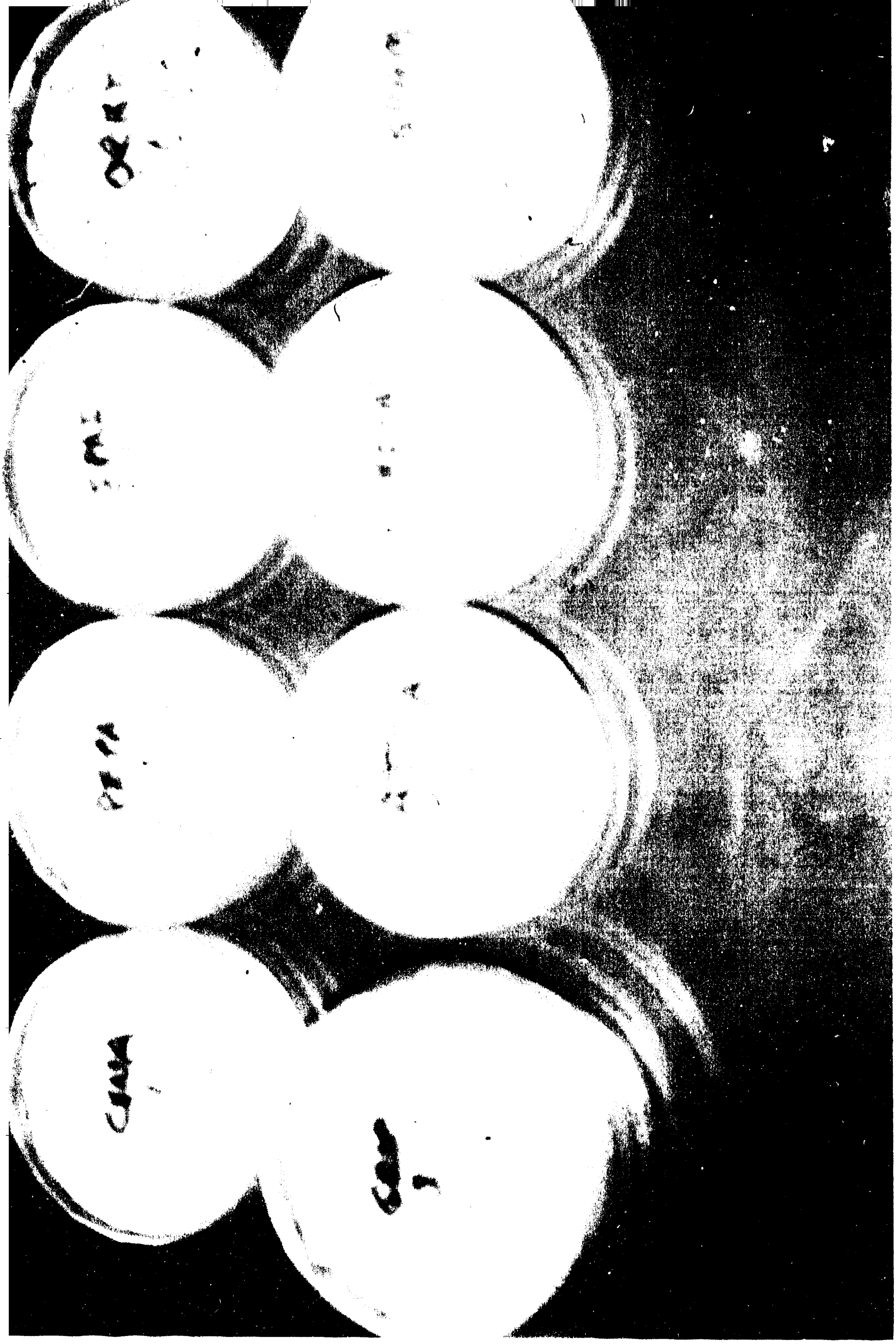

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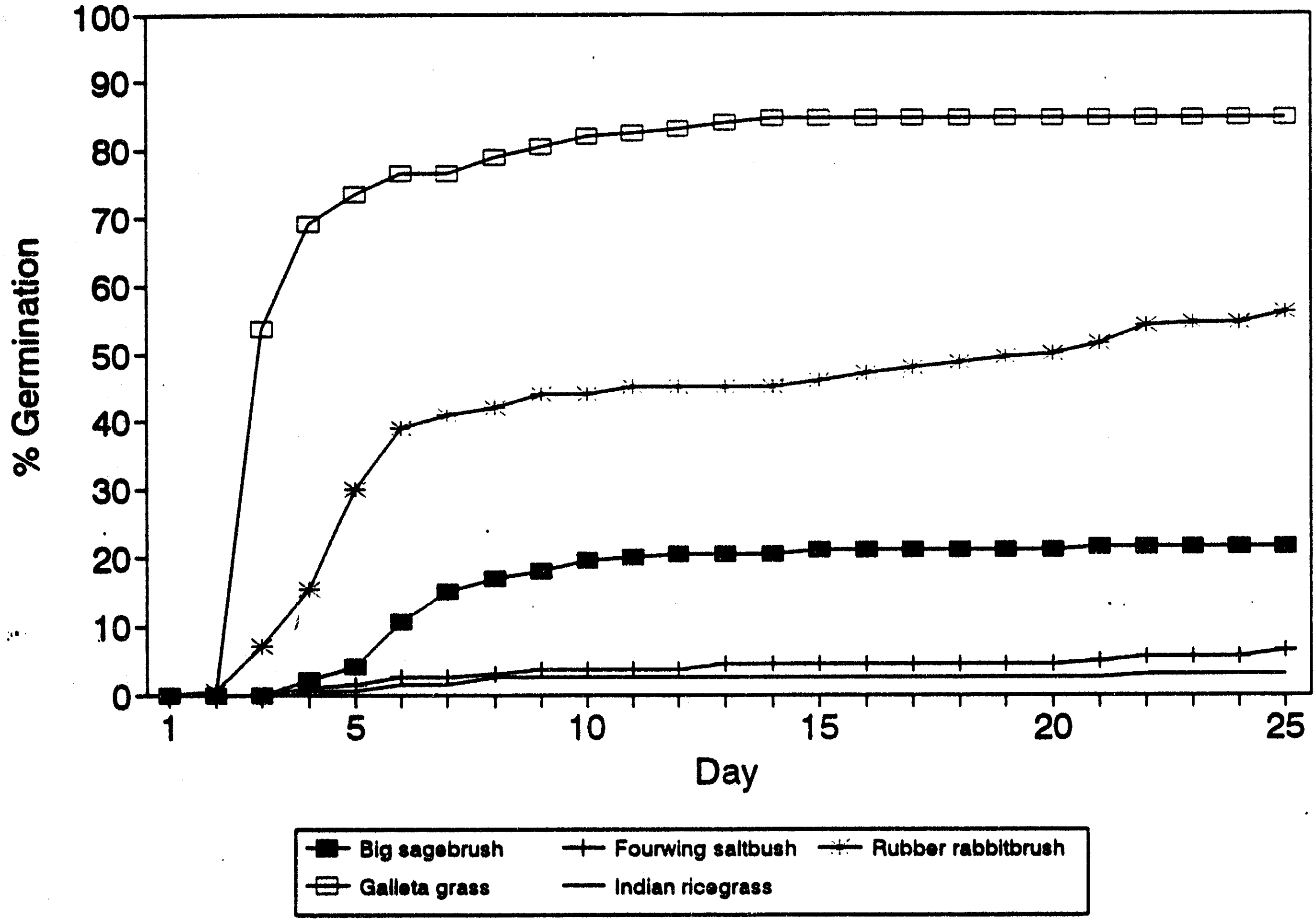
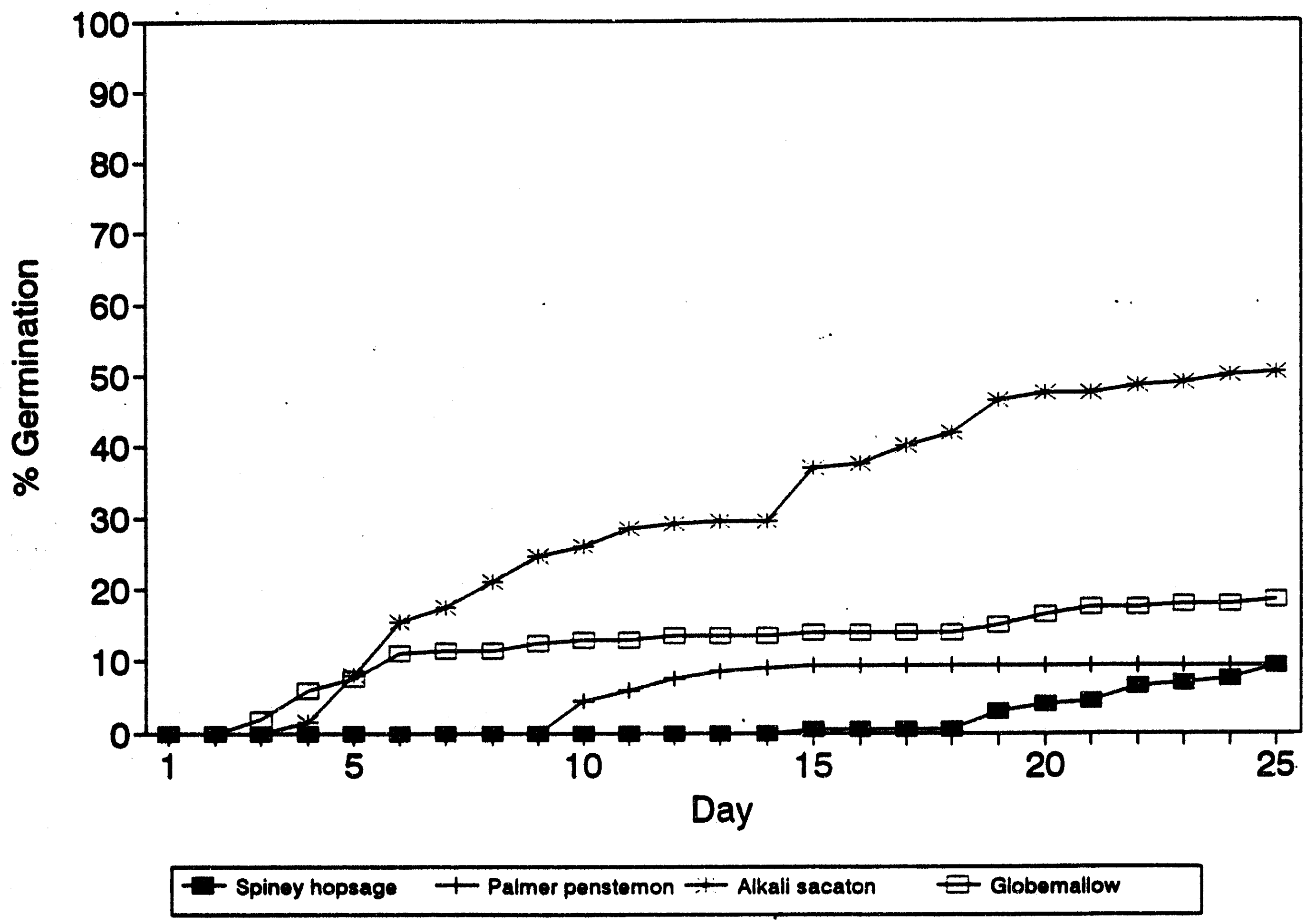
Results

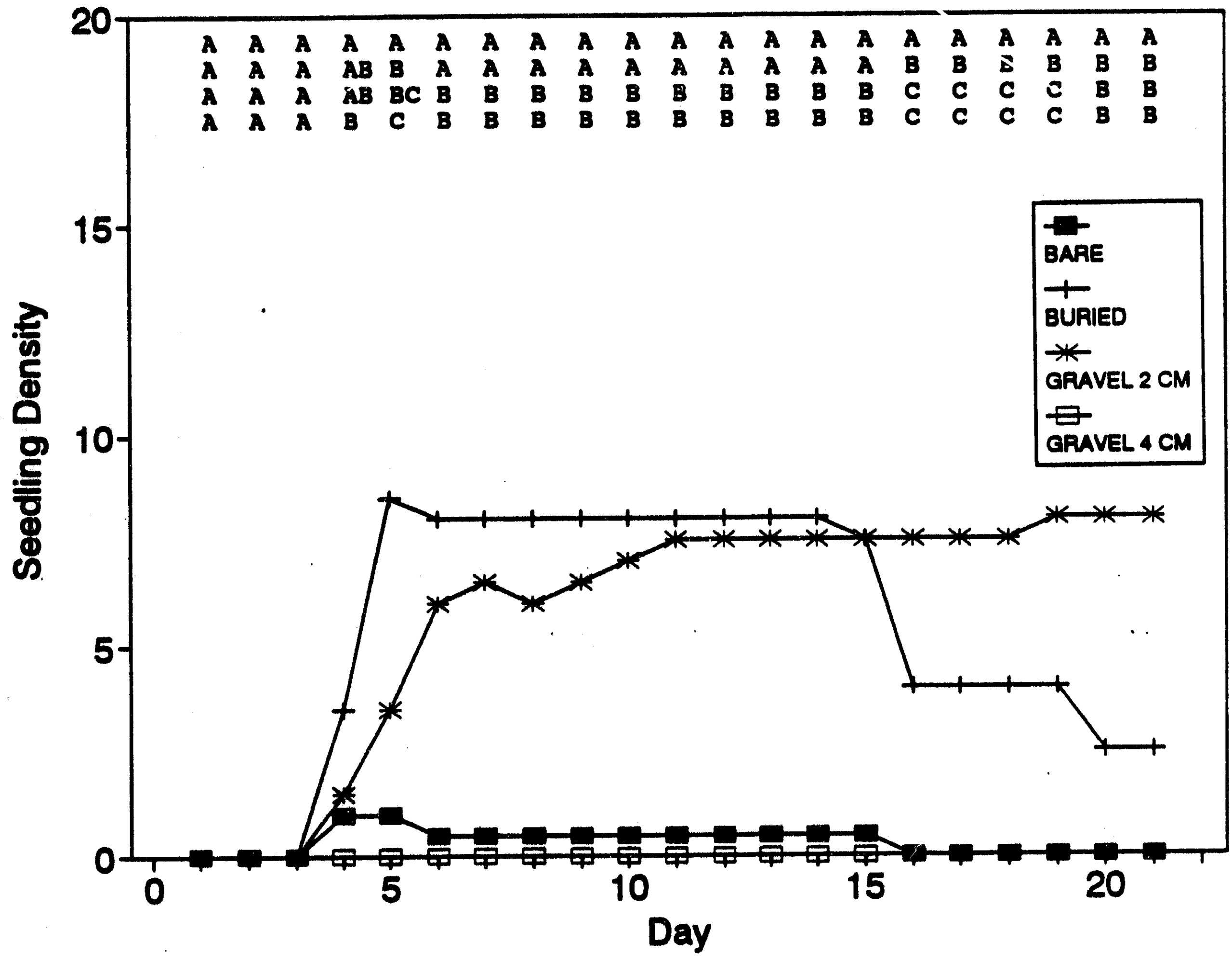


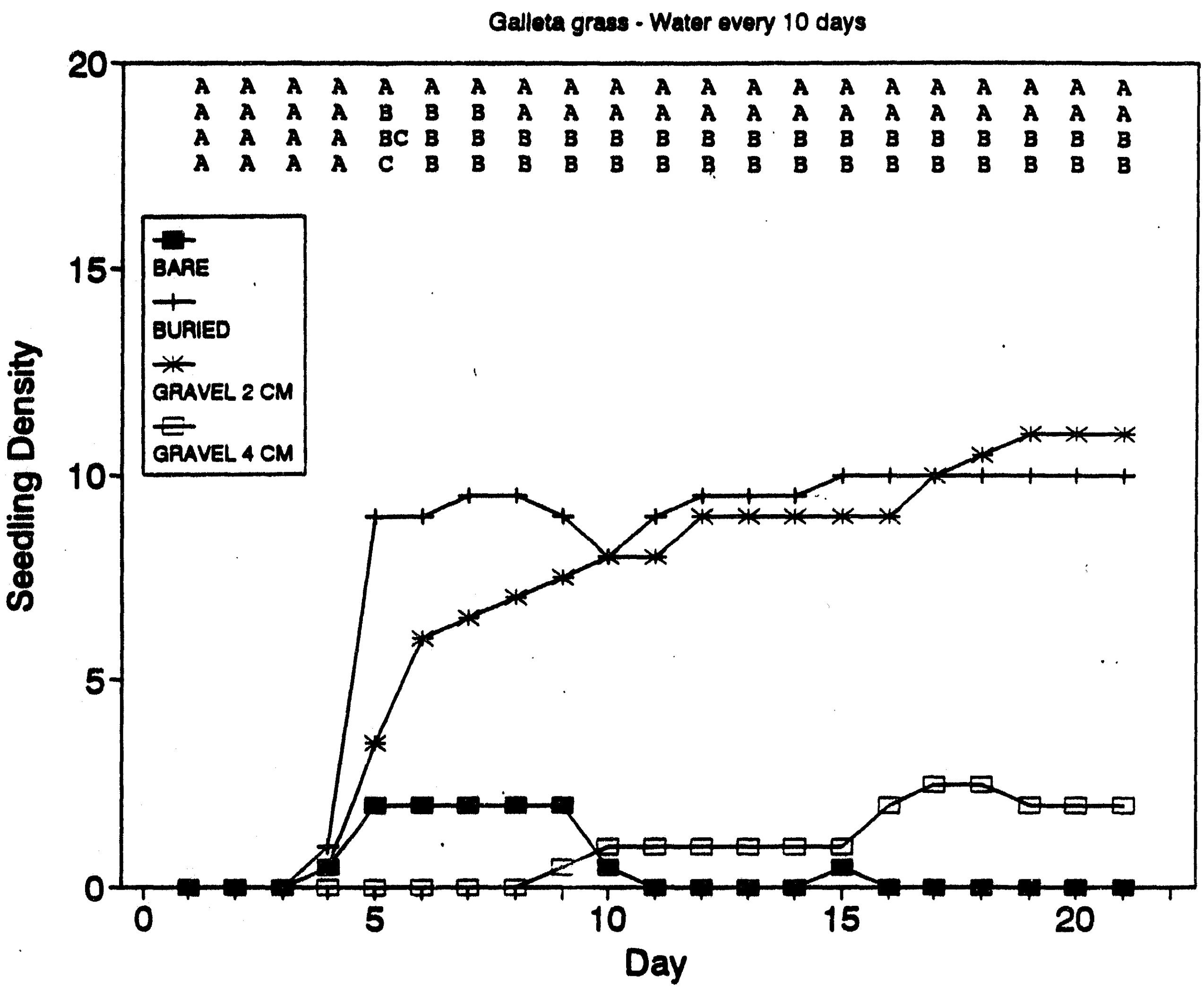
100
90
80
70
60
50
40
30
20
10
0
% Germination
1
5
10
15
20
25
Day
Big sagebrush
Fourwing saltbush
Rubber rabbitbrush
Galleta grass
Indian ricegrass



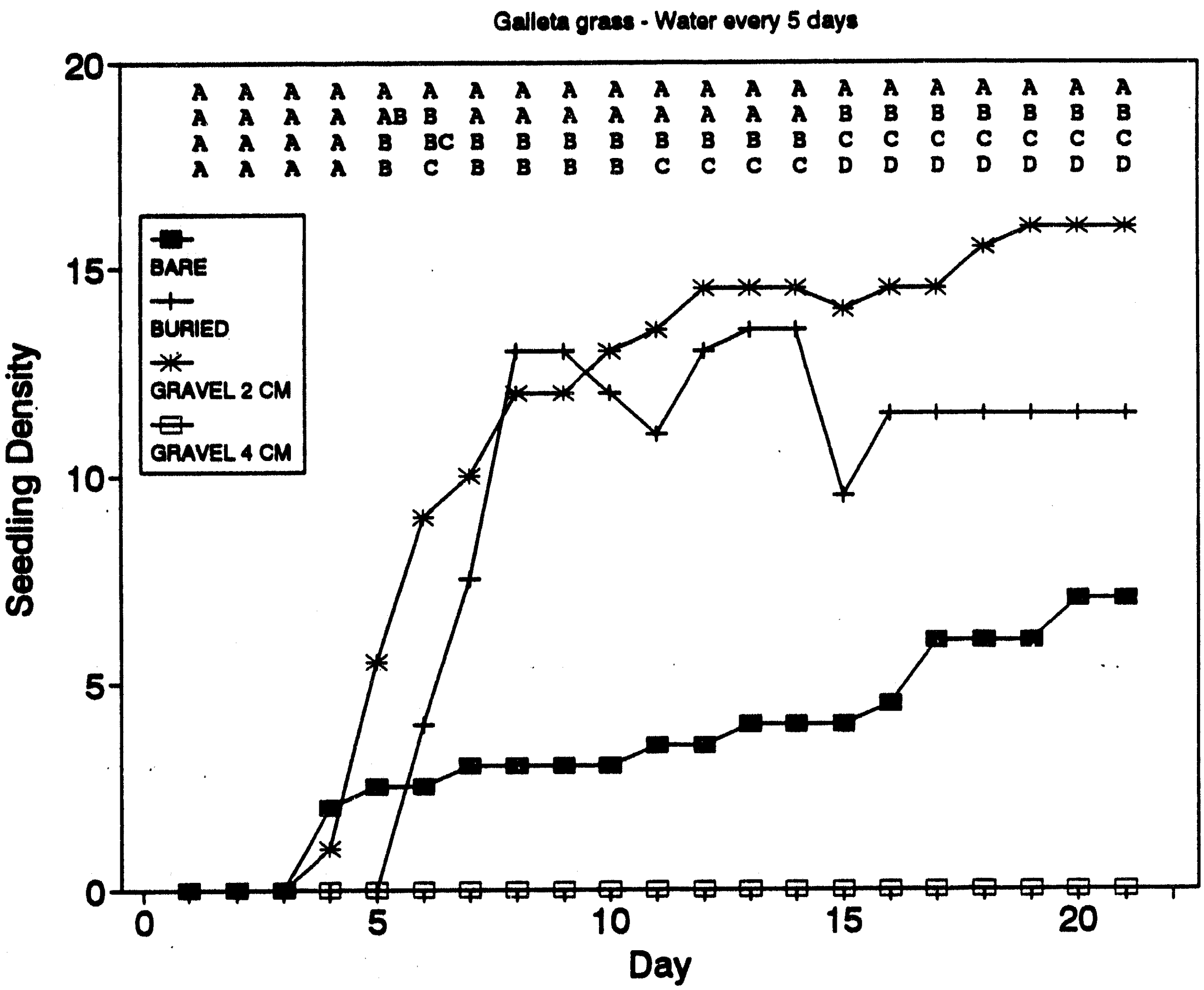
100
90
80
70
60
50
40
30
20
10
0
% Germination
1
5
10
15
20
25
Day
Spiney hopsage
Palmer penstemon
Alkali sacaton
Globemallow

Galleta grass - Water day 1 only

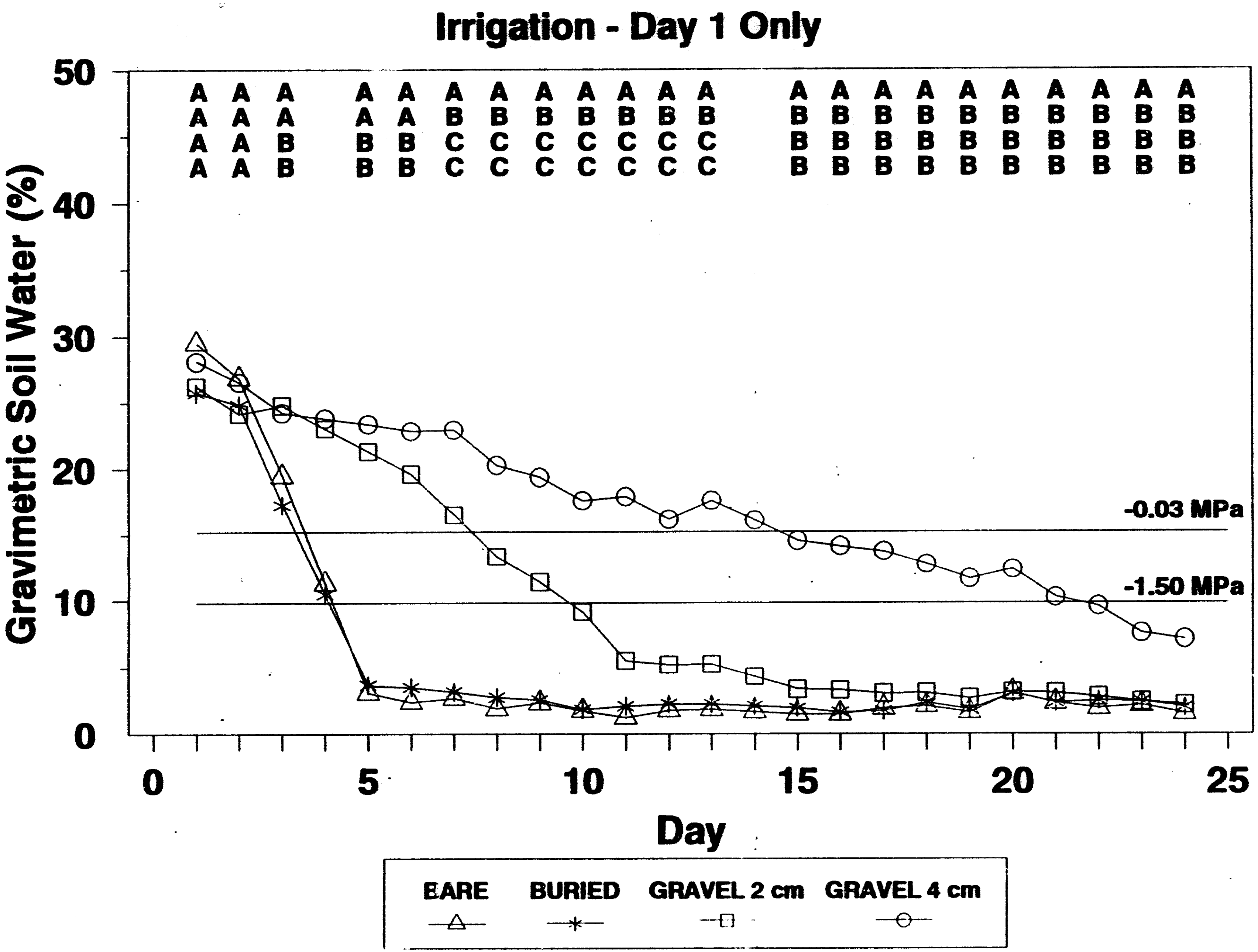




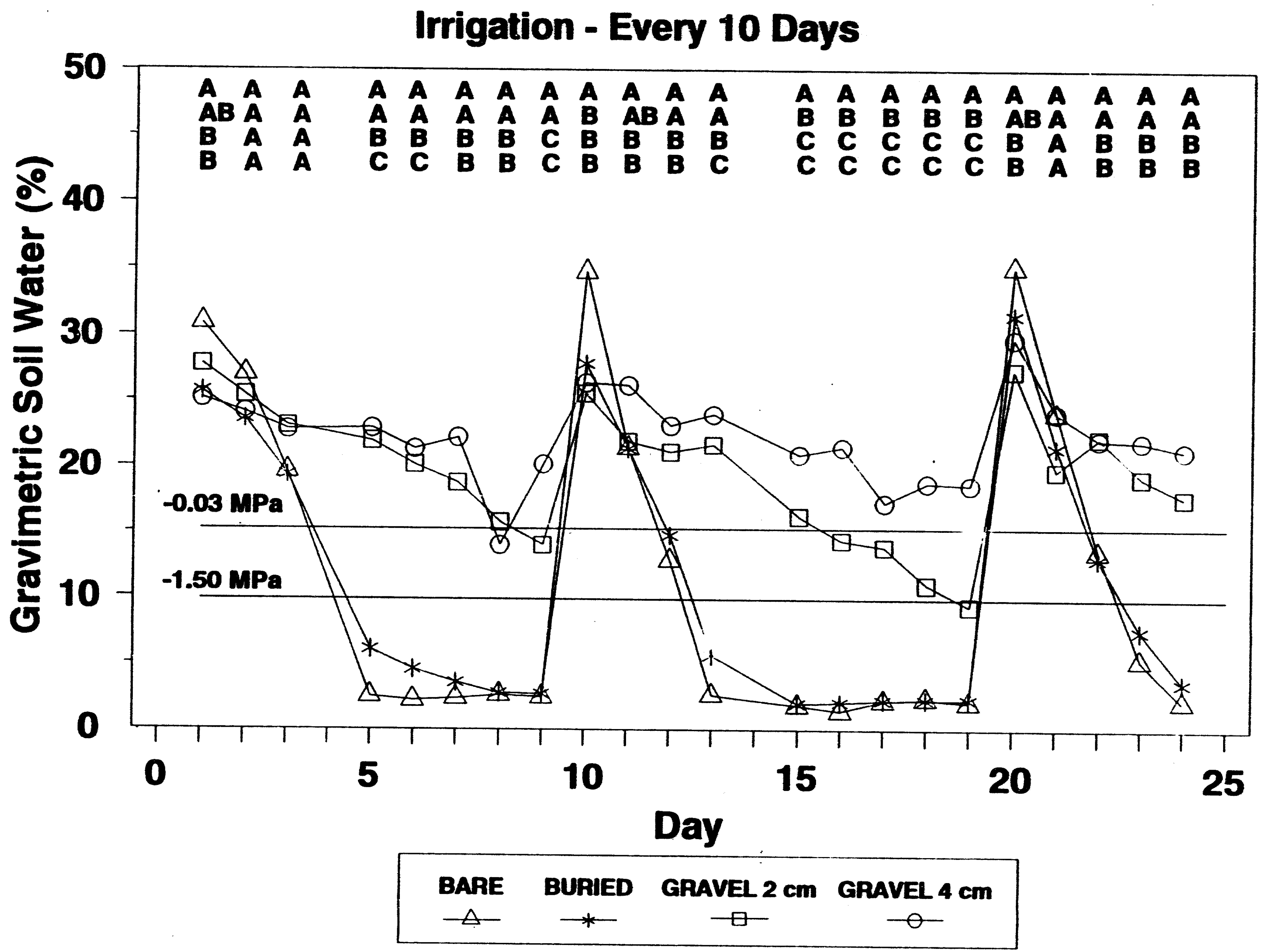
Galleta grass - Water every 10 days
Seedling Density
Day
20
15
10
5
0
0
5
10
15
20
BARE
BURIED
GRAVEL 2 CM
GRAVEL 4 CM
A A A A A A A A A A A A A A A A A A A A A
A A A A B B B A A A A A A A A A A A A A A
A A A A BC B B B B B B B B B B B B B B B B
A A A A C B B B B B B B B B B B B B B B B



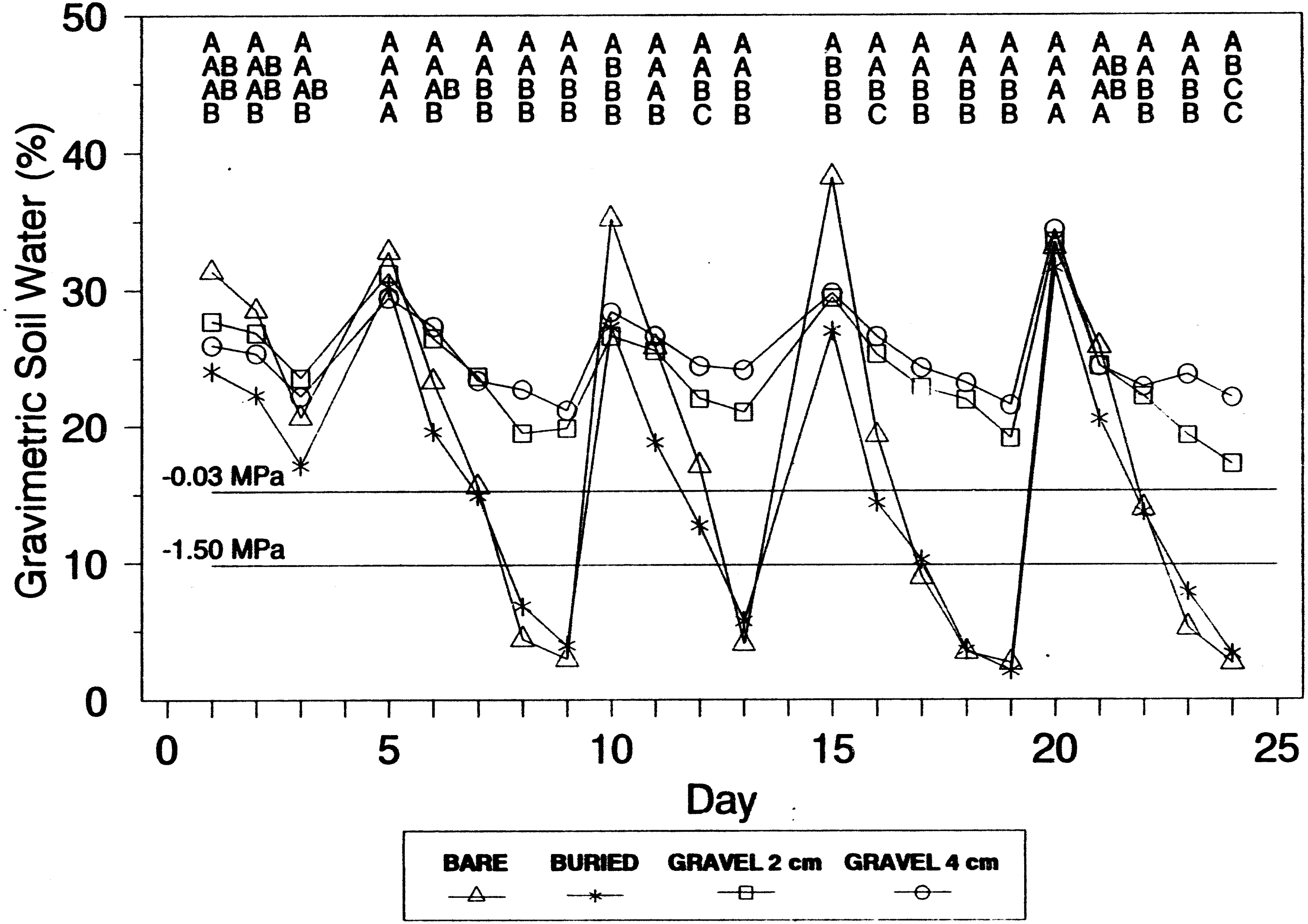
Galleta grass - Water every 5 days
Seedling Density
Day
BARE
BURIED
GRAVEL 2 CM
GRAVEL 4 CM



Irrigation - Day 1 Only
Gravimetric Soil Water (%)
Day
0
10
20
30
40
50
0
5
10
15
20
25
-0.03 MPa
-1.50 MPa
BARE
BURIED
GRAVEL 2 cm
GRAVEL 4 cm


Irrigation - Every 10 Days
Gravimetric Soil Water (%)
Day
0
10
20
30
40
50
0
5
10
15
20
25
-0.03 MPa
-1.50 MPa
BARE
BURIED
GRAVEL 2 cm
GRAVEL 4 cm

Irrigation - Every 5 Days



Conclusions

1. 2-3 cm gravel layer may aid emergence of galleta grass.

2. Gravel treatments conserved more soil water.

3. 4-5 cm prohibits emergence of galleta grass.

4. Galleta grass - possible model for other species

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