

Revegetation of Piñon-Juniper Woodlands with Native Grasses¹. Geneva Chong²

Abstract.— In 1978 Earth Environmental Consultants, Inc. estimated that some regions in Bandelier National Monument in northcentral New Mexico, were experiencing erosional soil losses of 0.5m/100yrs— an unsustainable rate in an area where soil may only be 0.5m deep. The abnormally high rates of erosion are most likely the result of past land use and management practices which have reduced herbaceous groundcover and left large expanses of bare soil. Results from several ongoing studies in the Piñon-Juniper Woodland at Bandelier National Monument indicate that, despite the protection to the land provided by the status of being a National Park, the downward trends in this ecosystem continue. Thus it appears that the eroded condition of the land cannot be improved rapidly enough to save the soil without active management. The studies included in this report are: 1) vegetation surveys from grazing exclosures established in 1975; 2) comparisons of herbaceous vegetation in tree interspaces vs canopied areas; 3) vegetation transects to determine percent cover by species and cover type (i.e. bare soil or cryptogam); and 4) a greenhouse experiment to study the effects of cryptogamic (microphytic) crusts on native grass seed germination. The results of these studies are respectively: 1) the removal of grazing pressure does not result in automatic increases of grasses and other herbaceous groundcover; 2) more herbaceous groundcover occurs in canopy interspaces suggesting that high tree densities may prevent establishment of herbaceous groundcover and thus increase erosion; 3) bare soil may be as high as 50% with vegetative cover as low as 10%, while cryptogamic crust cover may be as high as 30%; and 4) cryptogamic crusts may inhibit seed germination. Finally, a revegetation experiment which compares three tree thinning treatments and six seeding (native grasses) treatments is described, and results from one growing season are discussed. Results from the revegetation experiment will be used to treat selected areas in Bandelier National Monument and can be applied to similar ecosystems with similar erosion problems.



INTRODUCTION

Much of the Piñon-Juniper (*Pinus edulis* and *Juniperus monosperma*) woodland at Bandelier National Monument in northcentral New Mexico currently experiences unsustainable, and most likely accelerated rates of erosion (Earth Environmental Consultants, Inc., 1978). The erosion occurs in many areas where herbaceous understory is absent or sparse, which leaves expanses of soil exposed to high intensity rainfall. This paucity of herbaceous groundcover is probably the result of past grazing, fire suppression which allows increased tree density (Barney and Frishknecht 1974) and possibly a drier climate.

In addition to the loss of natural resources due to erosion, the structures and the information contained within the thousands of archaeological sites which Bandelier was created to protect are being destroyed. In a five year survey of 40% of the park over 2000 archaeological sites were recorded and 70% of these were damaged by erosion (Sweetland, Archaeologist, personal communication.) The majority of these Anasazi ruins are unexcavated. Thus, as erosion destroys the chronological layers within them, all their information is lost.

To reduce erosion at Bandelier it is desirable to increase herbaceous groundcover, but this must be done in ways acceptable for use in wilderness areas and around archaeological sites. A better understanding of the ecosystem is also necessary to ensure that revegetation methods will be ecologically acceptable and self-sustaining.

To address the erosion problem I ask two main questions: 1) what determines presence, trends and amount of herbaceous groundcover and 2) what is necessary to re-establish self-maintaining herbaceous groundcover (i.e. native grasses). The goal of my research is to determine the most effective methods for increasing herbaceous groundcover (grasses) to stabilize bare, eroding soil in the PJ woodland at Bandelier. Effectiveness in this case is judged by survivorship and reproduction of native grasses.

The benefits of increased grass cover include: 1) the provision of fuel for wild or prescribed fire which in turn provides for; 2) maintenance of a

more open woodland favorable to both grasses and trees (this through the combined actions of fire and herbaceous groundcover which prevent excessive tree seedling establishment) (Burkhardt and Tisdale 1976); 3) protection of the soil from unsustainable rates of erosion; and 4) provision of food for wildlife. As part of this study I hope to gain insight into the factors which control the structure of the ecosystem. In this paper I present results from several supporting (and ongoing) studies designed to characterize the ecosystem and help determine the most effective revegetation methods using tree thinning and native grass seeding treatments.

SUPPORTING STUDIES

Burro Exclosures

Analysis of vegetation data from three sets of burro exclosures that were established in 1975 (Koehler 1974) shows that although there are differences between the three types of exclosures: 1) open to grazers, 2) five strand barbed wire fence to exclude feral burros, cows and elk, and 3) woven wire fence to exclude virtually all grazers (fig. 1), few or no significant overall increases of vegetative cover have occurred (fig. 2) (Potter 1985, Chong 1992, unpublished report). This implies that even with total removal of grazing pressure, 18 years is insufficient time to achieve a significant increase in ground cover and thus a reduction in erosion. With an erosion rate estimated at 0.5m/100yrs, simple protection from grazing is clearly not enough to create and maintain a stable ecosystem.

Vegetation Transects

Permanent vegetation transects (300m each, n=10) are used at Bandelier to describe an area's composition in terms of species' presence and abundance as well as groundcover (i.e. soil, litter, cryptogam, rocks, etc.). Results show that some areas of the park have a surface condition of 50% bare soil

with herbaceous vegetation covering only about 10% of the ground. These transects also show that up to 30% of the surface can be covered by microphytic crusts (or cryptogamic crusts) (fig. 3) (Bandelier, unpublished data 1992).

Microphytic Crusts

In a greenhouse experiment comparing numbers of seedlings on potting soil, disturbed crust and intact crust I found that there were significantly fewer seedlings on the intact crust (fig. 4) (Chong, unpublished data 1993). This result has negative implications for seed germination in areas of the park with large amounts of cryptogamic crust. However, in the greenhouse seeds that were able to germinate on the crust have outlived those on the other two soil types which is most likely a result of improved moisture status associated with the crust (see also: Brotherson et al 1983; Lesica and Shelly 1992) Thus a multiplicity of factors may contribute (both positively and negatively) to the spread of herbaceous groundcover in regions with large amounts of crust.

Canopied vs. Interspace Location

Analysis of data collected at the revegetation study site reveals that there is significantly more herbaceous groundcover between (interspace) than beneath (canopied) trees (fig. 5) (Chong, unpublished data 1993). This suggests that trees may be outcompeting herbaceous plants. Possibly of more interest are the results which show that larger trees (assumed to be older as well) have more cover beneath them than do smaller trees, and these differences are statistically significant in the case of *Juniperus monosperma* (fig. 6) (Ibid.). Treering studies show that historically stands of *Pinus ponderosa* which surround my study site experienced a mean fire interval (MFI) of 15.5 years until the late 1800's (Allen 1989). It is likely that the fires spread into the PJ areas of my study site and would have served to kill young

trees thus causing the woodland structure to contain more older trees with their associated herbaceous groundcover.

Conclusions from the Supporting Studies

In summary the results of these four studies are: 1) long-term exclusion of grazing does not necessarily result in increased herbaceous groundcover; 2) some areas in the park may have up to 50% bare soil, 10% herbaceous cover and 30% microphytic crust cover; 3) in the greenhouse microphytic crusts inhibit seed germination and 4) tree interspace areas and larger junipers have significantly more herbaceous groundcover associated with them than do canopied areas.

These results indicate that active management may be necessary in order to increase herbaceous groundcover and thus reduce soil erosion in a timely manner in the Piñon-Juniper woodlands of Bandelier National Monument. Management practices such as prescribed burns, prescribed natural fire and control of grazer populations are appropriate, but alone they are not sufficient to increase herbaceous populations since in many areas seed sources are apparently absent. Thus, in the following sections I address an ongoing experiment designed to determine the most effective methods for increasing native grasses through seeding and tree thinning treatments.

REVEGETATION EXPERIMENT

Methods

To provide resource managers with tested revegetation methods for use in the eroding Piñon-Juniper Woodlands in Bandelier National Monument and other similar ecosystems, a three-year revegetation experiment was begun in March 1991. The objective of this research is to determine the most effective revegetation methods using native grass seed in combination with thinning, mulching and fertilizing treatments. Success is measured by numbers of live

grass seedlings. This project is designed to conform to several constraints including: space, funding, and National Park Service requirements (i.e. for use in wilderness areas and on archaeological sites).

In a two way factorial design to look for possible interactive effects between tree thinning and seeding treatments, nine 26 m x 39 m blocks are evenly divided between three tree thinning treatments: 1) thinning with slash left, to act as a mulch; 2) girdling, to leave standing dead trees to simulate the use of pelletized tree herbicide; and 3) no thinning (control). In the thinning process only the smallest trees were removed to achieve 10-15% tree cover and thus simulate the thinning effects of fire.

Within each block 6 plots are randomly allocated to one of 6 seeding treatments: 1) control; 2) disturbance (to determine if a seed bank is present and inducible); 3) addition of seed; 4) seed and mulch; 5) seed and fertilizer; and 6) seed, mulch and fertilizer. The disturbance plots and plots that were seeded were raked to a depth of 5-7 cm with a blade-tined rake. Native grass species used in the seeding treatments are: *Schizachrium scoparium*, *Bouteloua gracilis*, *B. curtipendula*, *Hilaria jamesii* and *Sporobolus cryptandrus*. (Common names are little bluestem, blue grama, sideoats grama, galleta grass and sand dropseed, respectively.)

Each plot contains a grid of 12 permanent monitoring points. Thus each block contains $6 \times 12 = 72$ monitoring points. Before treatments a 0.9 m x 0.6 m frame was centered over each permanent monitoring point. I photographed the area within the frame and visually estimated the percent groundcover by species. All photographs will be retaken annually and scanned onto compact disks so that vegetative cover can be tracked and compared through time by computer. I mapped the woody vegetation of each plot in detail to provide a record of which points were originally under trees, which points were in canopy interspaces, and which points would remain under trees after thinning. I used this data in an analysis of variance to test for the effects of trees on herbaceous groundcover (see the Supporting Study "Canopied vs. Interspace Location"). Thinning treatments were applied between March and May 1992 and seeding occurred in the end of June 1992. Three months after planting, I

photographed the sample points within the frame again and counted the number of grass seedlings in situ.

RESULTS

Pretreatment data were used to compare the amount of herbaceous groundcover beneath and between piñon and juniper trees. I used analysis of variance (ANOVA-SAS Institute Inc. 1988) to compare 200 sample points from under trees to 200 points located between trees. There was significantly more vegetation between trees (fig. 5) which indicates that tree thinning may increase revegetation success. A comparison of tree species by size found that there is more vegetation under older (larger) trees (fig. 6). This supports my decision to cut younger (smaller) trees during thinning to simulate the effects of fire on a woodland structure.

Results from an ANOVA on success of revegetation methods after one growing season were obtained by comparing numbers of seedlings for each treatment combination. Despite the pretreatment results which indicated that tree cover may reduce herbaceous groundcover, block treatments (tree thinning) showed few significant differences (fig. 7). However, these results reflect an early stage in the experiment, and the effects of these treatments may become significant over time. For example, grasses in blocks mulched with tree branches (slash) may experience reduced herbivory and benefit from the release of nutrients and organic matter as the wood decomposes. Grasses in either of the thinned treatments (cutting and girdling) may also experience decreased competition for soil moisture. Thus treatment differences due to improved microclimates may become apparent at a later time in the experiment.

Analysis of the plot treatments (seeding, fertilizing and mulching with straw) also resulted in few significant differences after seed application (fig. 8). However, the addition of seed alone was statistically equal to or better than adding seed with other ammendments. The absence of significant numbers of seedlings in the control and disturb plots may indicate the lack of a seed bank and thus the need for seed application. If long term results

confirm that seed application alone results in significant numbers of grass seedlings then the solution to increasing herbaceous groundcover may be more simple than expected. It suggests that these Piñon-Juniper ecosystems may recover if given a "jump start" by providing seed (since on-site seed sources may be absent.)

As with the tree thinning treatments, long term survival and reproduction of seedlings may be improved in mulched and/or fertilized plots. The straw mulch may improve soil moisture, organic matter, and nutrient content thus leading to increased growth, survivorship and reproduction of the plants. Fertilizer could have similar effects. However, preliminary results suggest that it does not enhance seedling establishment, and due to the expense this treatment will probably not be repeated in the future.

In summary, treatments that are statistically insignificant after only one, short growing season may produce significant results in future years. This may become more evident as more data sets are collected this spring and fall (1993). In the spring of 1993 I will recount live seedlings. In the fall of 1993 I will photograph the points again, count live seedlings, identify them by species and count seed heads as a measure of reproduction. With this information I will determine survivorship and reproduction related to the different treatments and thus the most successful revegetation method(s) for use in Piñon-Juniper woodlands like those at Bandelier.

CONCLUSION

Recent information gathered on the piñon-juniper woodlands at Bandelier National Monument indicates that active management is necessary to reduce current rates of erosion through an increase in herbaceous groundcover. Reduction of erosion is necessary to preserve cultural and natural resources which the park is mandated to protect. Tree thinning and application of native grass seed may provide one solution for helping the ecosystem return to a more stable and self-sustaining state. Regardless of the actions decided upon, it is imperative that the land manager understands the ecosystem(s) within which

he/she works. Without this understanding ten years down the road someone may look out across the landscape and wonder what can be done to mitigate past management.

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FOOTNOTES

1. Paper presented at the Piñon Symposium, April 27, 1993, Santa Fe, New Mexico. A summary of ongoing Piñon-Juniper Woodland revegetation research at Bandelier National Monument, New Mexico.
2. Geneva Chong is a student trainee/biological technician who is conducting her research at Bandelier National Monument, Los Alamos, NM and completing an MS in Biology at the University of New Mexico, Albuquerque.

FIGURE CAPTION LIST

Figure 1. Results of a canonical discriminant analysis (SAS Institute 1988) used to look for differences between grazing exclosure treatments shows that plots are significantly different due to differences in species present (Chong, unpublished report 1992). These differences are not related to amount of herbaceous cover as cover did not necessarily increase with the exclusion of grazing (see also fig. 2). 1=open to grazers, 2=5 wire fence (excludes burros and cows), 3=woven wire fence (all but small mammals excluded). The points' positions on the x-axis are influenced by the presence of five "rare" grasses (possibly sensitive to grazing): *Lycurus phleoides*, *Aristida purpurea*, *Sitanion hystrix*, *Bouteloua eriopoda*, and *B. curtipendula*.

Figure 2. San Miguel Burro Exclosures: an example which demonstrates changes in herbaceous cover by species over 14 years. There have been no significant increases in grass coverage (arpu, bogr, muta, pobi, sihy, spcr, gras) despite total exclusion of grazers (via a woven wire fence) (Potter 1985; Chong, unpublished report 1992).

Figure 3. Results from 10 vegetation transects at Bandelier National Monument show that in some areas of the park bare soil comprises almost 50% of the ground cover while cryptogams may cover over 30% of the soil surface. Grass cover may be as low as 2% (Bandelier National Monument, unpublished data 1991).

Figure 4. In a greenhouse study I compared seed germination on potting soil, disturbed cryptogamic (microphytic) crust and intact crust ("pot", "sand" and "crust", respectively). Significantly fewer seeds germinated on the intact crust (statistically significant differences are indicated by having a different letter above the bar.) (Chong, unpublished data 1993).

Figure 5. Areas located in open spaces at my Piñon-Juniper study site have significantly more herbaceous plant cover than do canopied areas (Chong, unpublished data 1993).

Figure 6. Larger, "old" trees have more herbaceous groundcover under them than do smaller, "young" trees at my study site. This is statistically significant in the case of *Juniperus monosperma* (jumo) which is statistically equivalent to an open area in terms of herbaceous groundcover (Chong, unpublished data 1993).

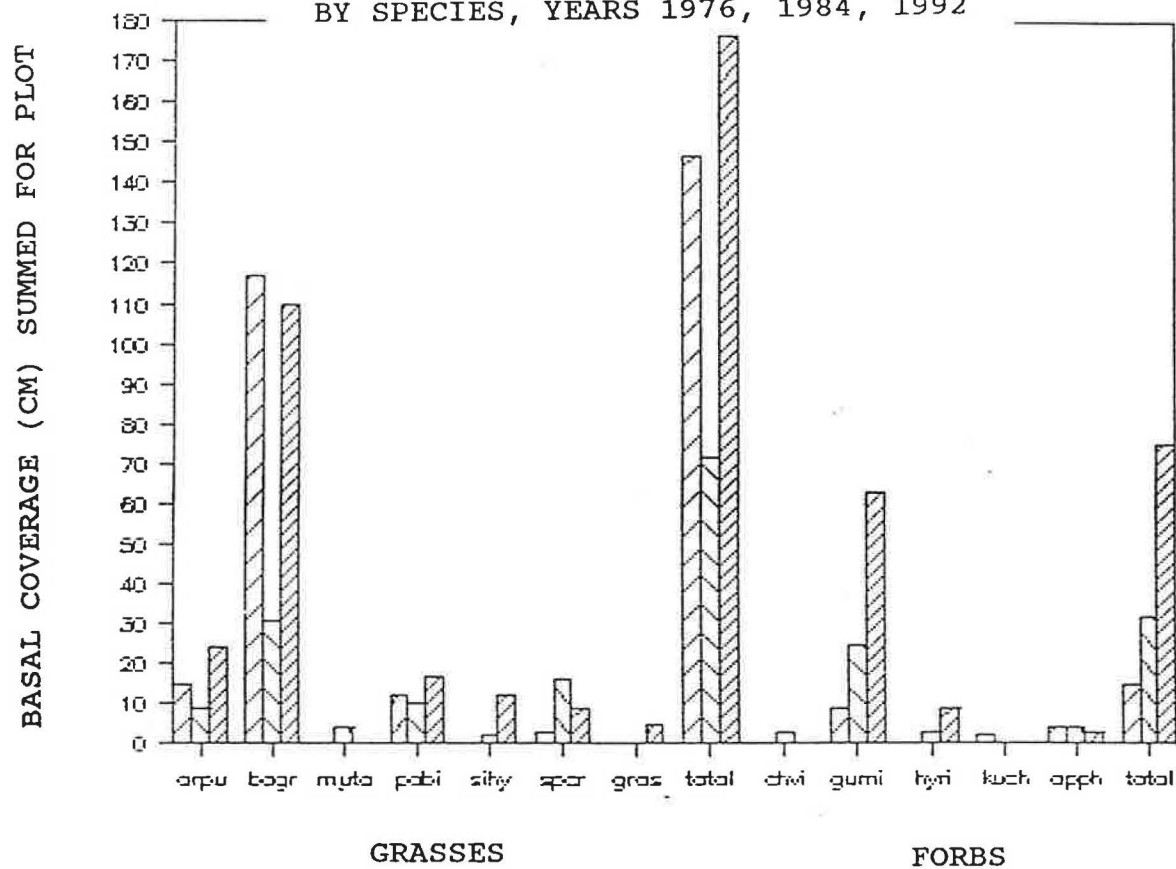
Figure 7. After one growing season tree thinning (block) treatments show few significant differences. However, the highest number of grass seedlings occurred in a cut block while the fewest were from a control block (Chong, unpublished data 1993). Significant differences may become apparent after the

second growing season. "cut"=small trees were cut and the slash was left as a mulch. "gird"=small trees were girdled to leave standing dead. "ctrl"=control where no thinning took place.

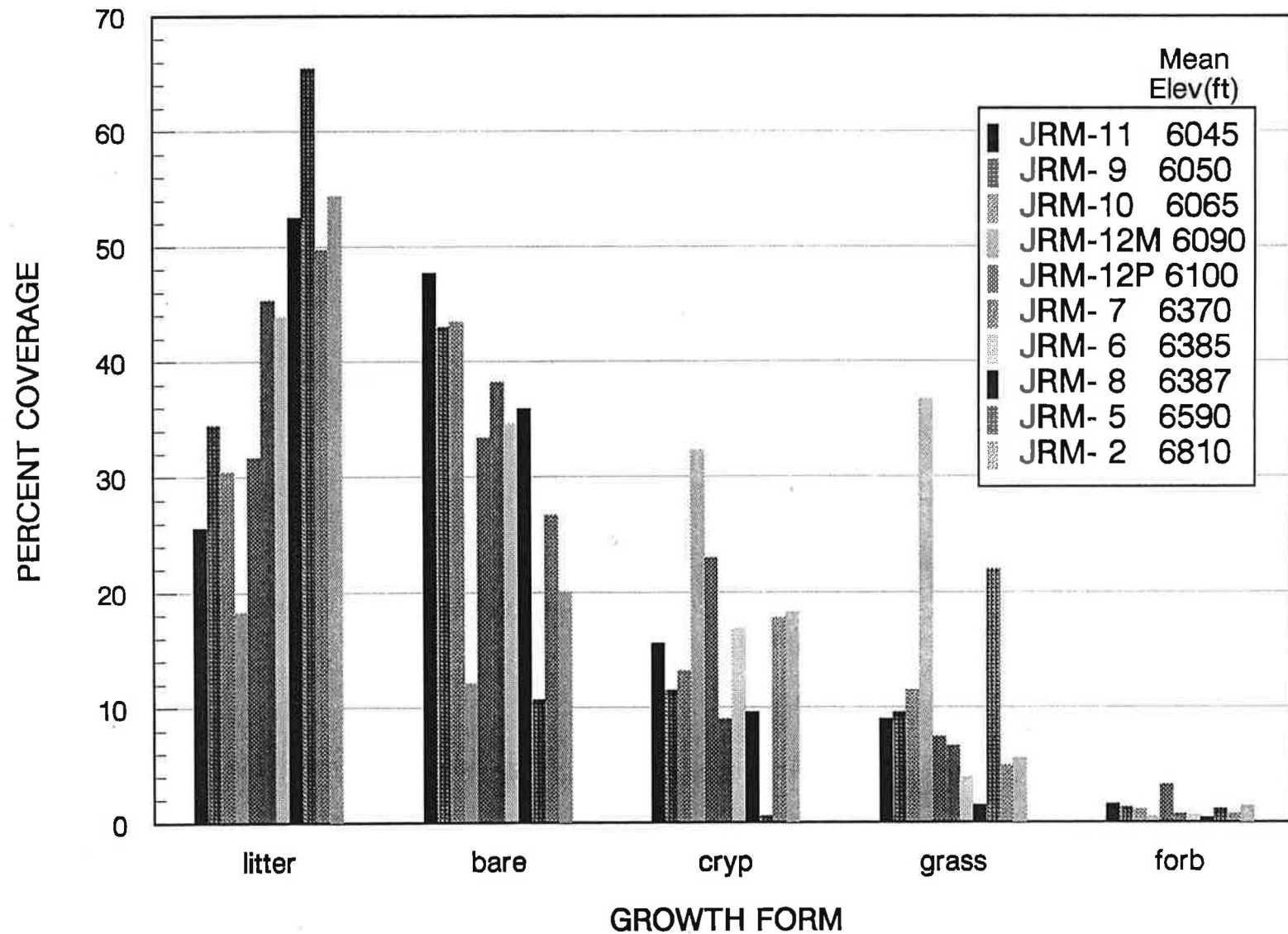
Figure 8. Between seeding (plot) treatments there were significant differences between adding seed and not which suggests an absent or inactive seed bank and the necessity of adding seed. Adding seed alone is statistically better than or equal to adding seed combined with fertilizer and/or mulch in terms of numbers of grass seedlings. Fertilizer and/or mulch may increase survivorship, however, which could result in significant differences between treatments in the future.

S.Mig (3), woven (3) basal cover (cm)

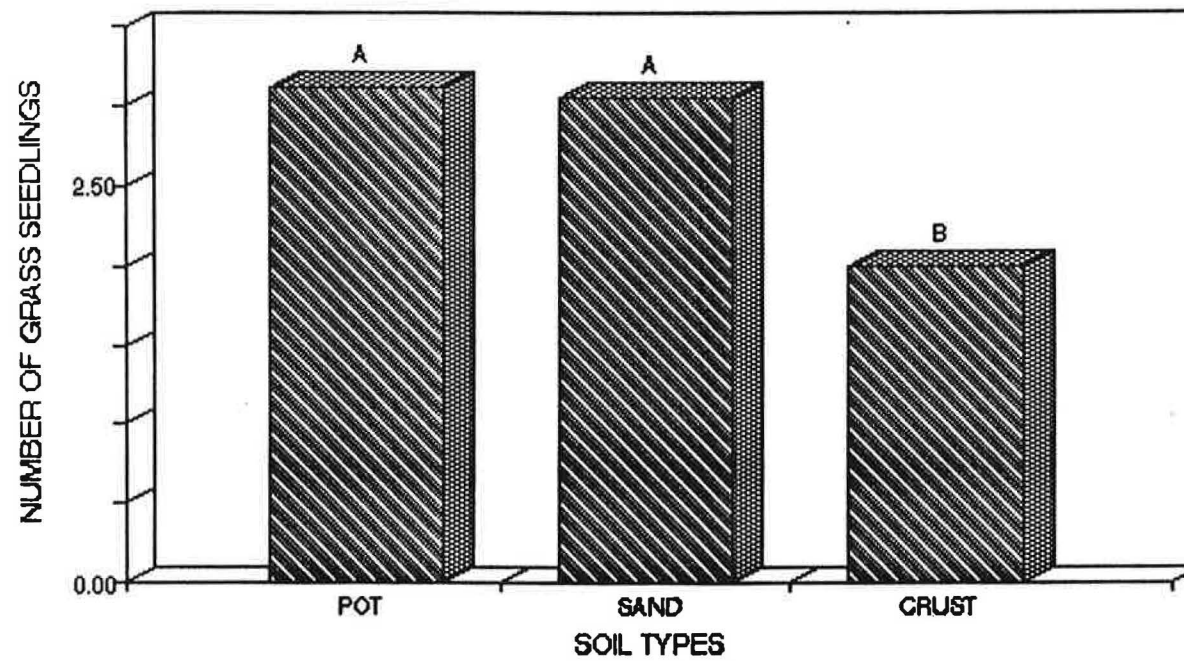
BY SPECIES, YEARS 1976, 1984, 1992



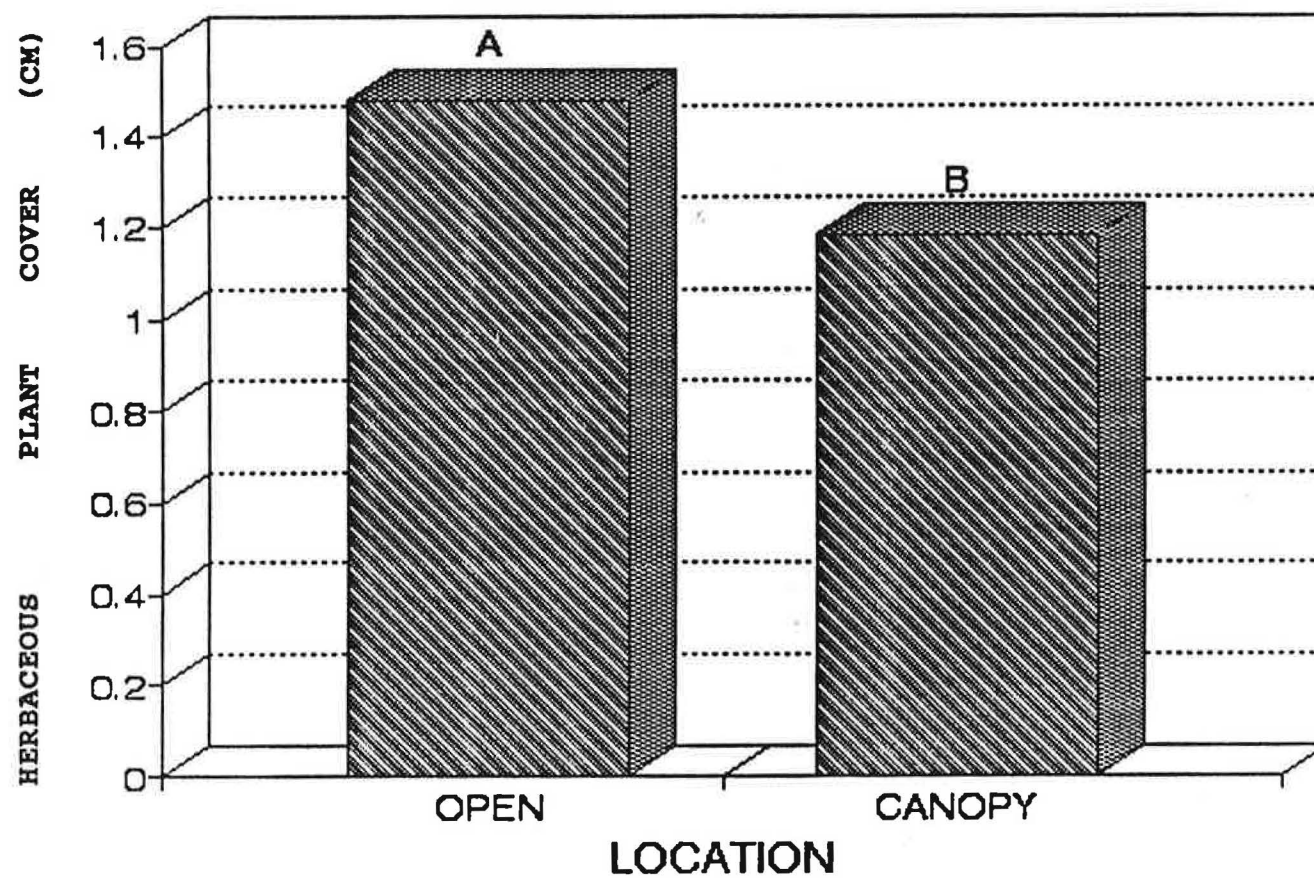
PLANT COVERAGE BY GROWTH FORM



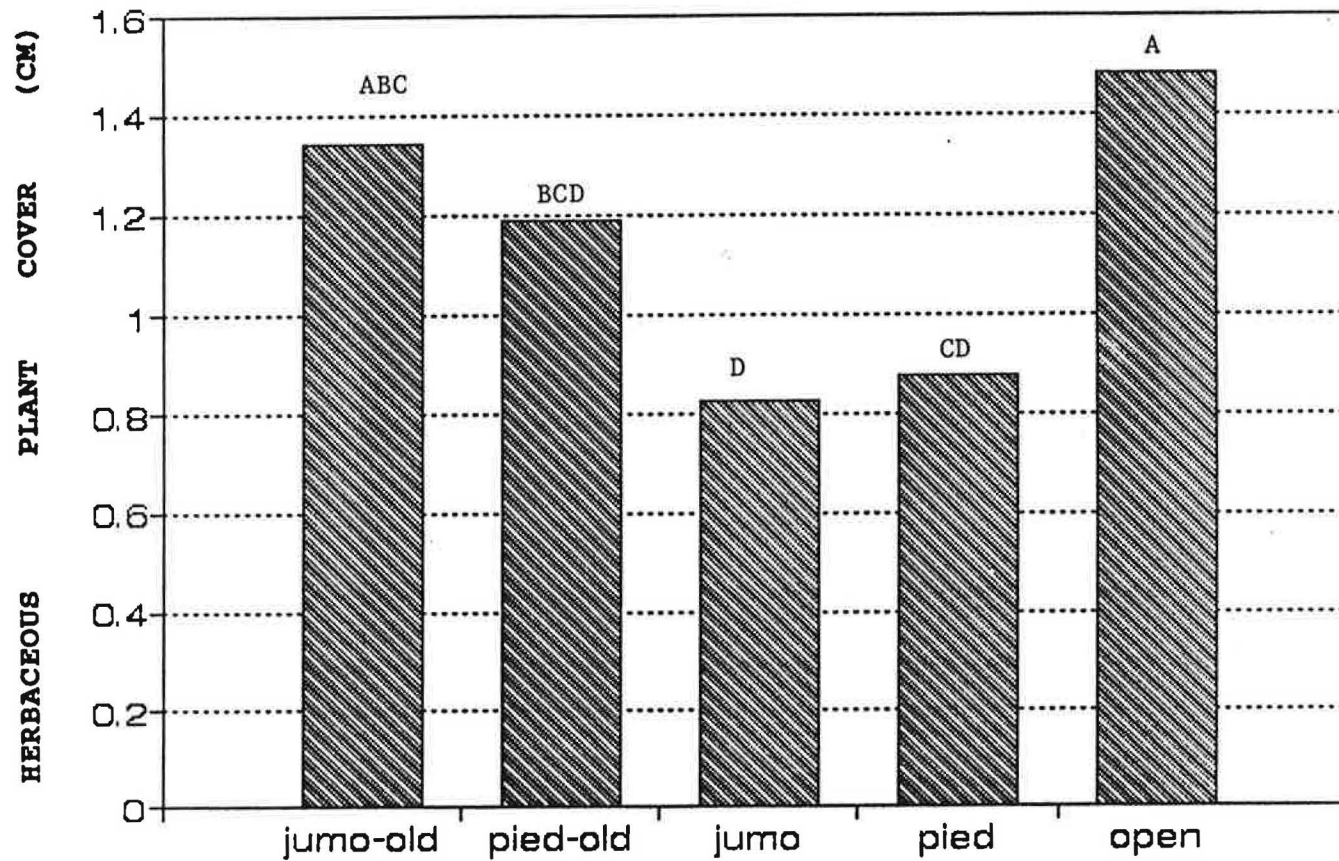
SEEDLING GERMINATION: COMPARISONS OF INTACT MICROPHYTIC CRUST,
DISTURBED CRUST AND POTTING SOIL



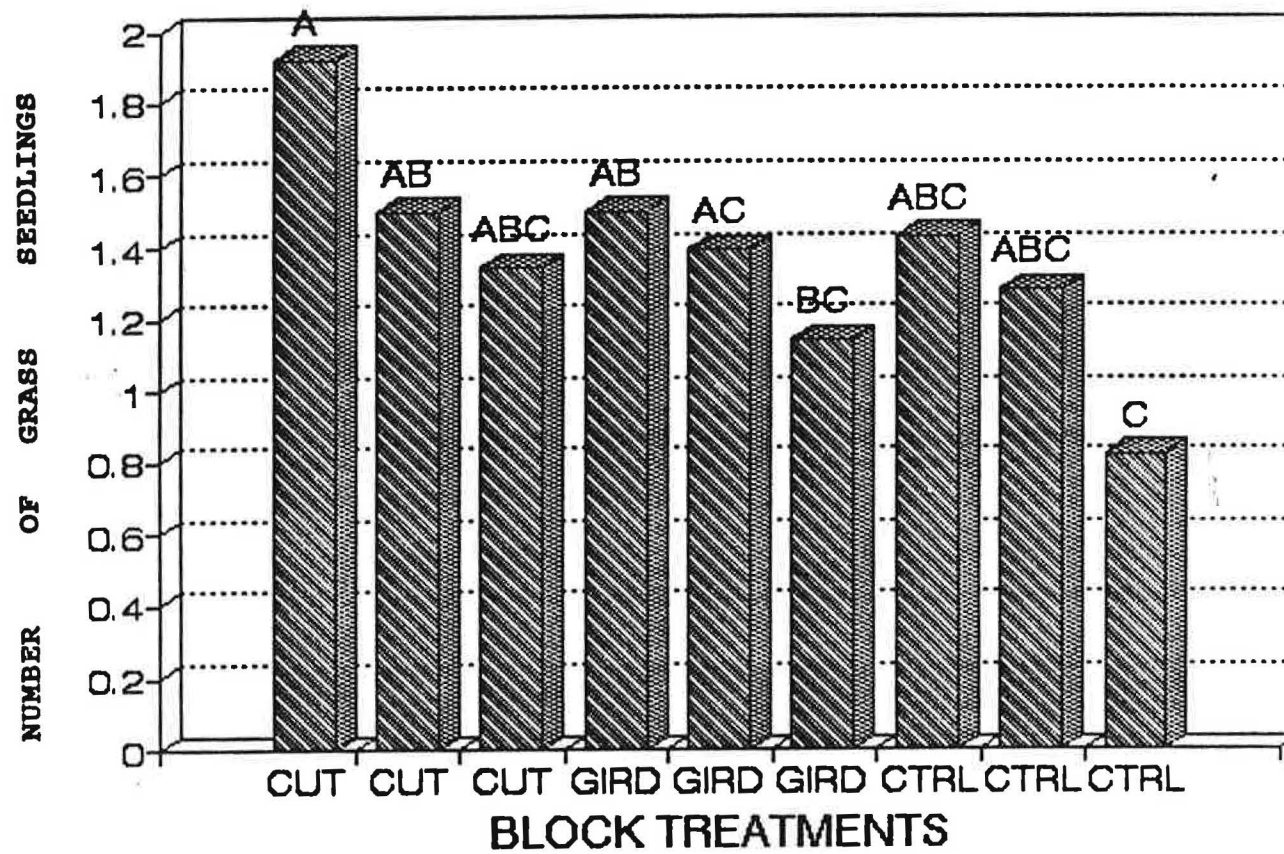
CANOPY VS. INTERSPACE: HERB.GROUNDCOVER



Herbaceous groundcover: canopy vs. open
comparing different tree species, ages



BLOCK BY BLOCK COMPARISONS



PLOT BY PLOT COMPARISONS

