AN ABSTRACT OF THE THESIS OF

Mabel Alejandro-Castro for the degree of Master of Science in Rangeland Resources presented on May 27, 1987.

Title: Influence of Cattle Grazing and Forage Seeding on Establishment of Conifers in Southwest Oregon.

Abstract approved: Redacted for Privacy
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The ability of controlled livestock grazing, in combination with seeding of palatable forages, to reduce understory competition and enhance conifer establishment, was evaluated during 1985 and 1986, on two adjacent sites in southwestern Oregon. In 1984, Site 1 was clearcut and broadcast burned to remove slash, and Site 2 was machine scarified, ripped to ameliorate compacted soil layers, piled and burned. Both sites were planted in the spring of 1985 with Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and ponderosa pine (*Pinus ponderosa* Dougl.) and the following treatments applied during both years: silviculture-control, native vegetation-grazed, seeded

vegetation-ungrazed, and seeded-grazed. Fifteen permanently marked 3.6m circular plots were located within each treatment replication, giving a total of 1950 trees from which growth and survival of conifers, and browsing and trampling by livestock and wildlife were monitored. Douglas-fir seedlings were also assessed for predawn and midday xylem potentials at each sampling date. Gravimetric soil moisture content and understory vegetation cover were also assessed on Site 1 and Site 2.

Interpretation of conifer survival and growth response was complicated by severe frost damage and heavy browsing by elk during the first year. Analysis of variance determined Douglas-fir survival and growth was not significantly different between treatments both years. However, a binomial response model describing predicted mortality of Douglas-fir indicated differences in survival were present. Mortality as predicted by the model was a result of the factors of frost, wildlife browsing, and livestock browsing and trampling, rather than treatment applications. Frost damage had the greatest impact on Douglas-fir mortality, both because it affected a large percentage of the trees on the site (43.6 percent overall), and because it dramatically increased seedling mortality. Elk, though impacting an equally large percentage of trees (23.1-57.7 percent), appeared to selectively browse the healthiest trees, or those not affected by frost damage. This resulted in much lower predicted mortalities. Although livestock browsing and trampling increased mortality of Douglas-fir seedlings, livestock activities were much less prevalent than wildlife browsing or frost. Each year, the controlled grazing program maintained livestock browsing at 2.6 percent, and trampling at 6.0 percent.

In 1985, early season, intense grazing by cattle did not result in treatment differences for Douglas-fir xylem potential. In 1986, the general trend was for seedlings growing in the seeded-grazed and silviculture-control treatments to have similar and less negative xylem potentials than trees growing in the seeded-ungrazed and native-grazed treatments. In 1986, gravimetric soil moisture content differed between treatments only during the June sampling date, when soil moisture content was significantly higher in the silviculture-control treatment. Total herbaceous and total shrub cover did not differ between treatments either year. The generally low xylem potential levels for seedlings in the seeded-ungrazed treatment, suggests seeding with similar forages and with the exclusion of livestock grazing in this area may result in increased water stress for Douglas-fir seedlings. Grazing improved the water relations of seedlings in comparison to ungrazed plots.

Influence of Cattle Grazing and Forage Seeding On Establishment of Conifers in Southwest Oregon

by

Mabel Alejandro-Castro

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed May 27, 1987

Commencement June 1988

APPROVED:

Redacted for Privacy

Professor of Rangeland Resources in charge of Major

Redacted for Privacy

Head of Department of Rangeland Resources

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Date thesis is presented May 27, 1987

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ACKNOWLEDGEMENT

During the last three years, many special individuals have offered their assistance in the completion of my graduate education. The students, faculty and staff of the department of Rangeland Resources have given me help in coursework and field work which was invaluable and much appreciated. I owe a well-deserved thank you to my major advisor, Paul Doescher, for his willingness to help throughout my graduate career, especially during the preparation of this thesis. I would also like to thank the other members of my graduate committee, Lee Eddleman, John Tappeiner, and my graduate council representative, Floyd Bolton, for their help in reviewing this thesis. Our department head, Bill Krueger, continually gave advice and support for this research project which proved to be necessary for its completion.

As part of my graduate career I had the privilege of working on this research for the Medford District of the Bureau of Land Management. I thank the District for financial assistance during the course of my field work, and I am grateful for the help and professional expertise offered by so many individuals there. Within the Butte Falls Resource area, I am especially thankful to Bill Drewein, John Simons, and Jim Harper who were always willing to answer an endless list of questions, and spent many extra hours in the field working on this project. Rob Lewis was instrumental in establishing my cooperative education program with the Bureau, and with getting this thesis project underway. They have earned my sincere appreciation and deepest respect.

As throughout all the trying periods in my life, I have been blessed with beautiful friends and a wonderful family supporting me along the way. I am happy to have this opportunity to extend a heartfelt thank you to Karen Leiendecker, Emily Rice, and Milda Vaitkus for caring so much. I especially thank Becky Brown, for her technical assistance in the field, and for her patience and genuine understanding.

I have yet to meet two finer people than my parents, Emilio and Lucy Alejandro, and two better friends than my sisters, Delis and Nydia. I thank you for loving me and for always respecting my decisions in life.

Finally, I would like to extend a very heartfelt thanks to my husband and best friend, David, for putting up with three years of stress, separation, and sometimes

unhappiness. Thank you for loving me enough to give me room to grow.

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INTRODUCTION

Establishment of conifers on forestlands of southwest Oregon is difficult due to xeric conditions and aggressive vegetation which establishes following overstory removal and site preparation. Herbaceous and woody vegetation occupying plantations compete with young conifer trees, reducing seedling survival and prolonging the period required for stand establishment (Cleary 1978). Vegetation management practices, through the release of soil moisture, nutrients and light, seek to improve growing conditions for the crop tree at the expense of undesireable vegetation.

In the Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) forests of western Oregon, vegetation management has traditionally been achieved through the application of herbicides (Cleary et al 1978). Public concern over possible health risks, and recent court decisions banning herbicide use on public lands, have prompted silviculturists to look for other methods of vegetation control (Leininger 1983).

There is currently much interest in using livestock grazing as a means of controlling competing vegetation in conifer plantations. Damage to conifer regeneration by livestock grazing in the past has left foresters skeptical of continued grazing on forest lands (Dutton 1953). However, studies have shown that when animal numbers and season of use are carefully controlled, grazing can be compatible with the establishment of conifer plantations (Black and Vladimiroff 1963, Hall et al 1959, Kosco and Bartolome 1983, Krueger 1983, Leininger 1983, McLean and Clark 1980).

Disagreement exists on the use of livestock grazing and seeding of palatable forages the first year of plantation establishment (Clark and McLean 1979, McDonald 1986). Seeding of palatable forages after conifer establisment can reduce shrub invasion into plantations (McDonald 1986). Seeding may be necessary on some sites to increase livestock utilization, ultimately improving control of understory vegetation. Plantation grazing literature lacks definitive information on the influence of livestock grazing and forage seeding on the survival and water relations of 1-year-old conifer seedlings.

In order to maximize the potential use of forest lands of southwestern Oregon for timber and animal production, research is needed to quantify the influence of cattle grazing and forage seeding on Douglas-fir establishment. The primary objectives of this research were:

1. to evaluate the impact of cattle grazing and forage seeding on the survival and growth of conifer seedlings,
2. to evaluate the influence of cattle grazing and forage seeding on the water relations of Douglas-fir, and
3. to evaluate the impact of cattle grazing and forage seeding on cover of understory herbs and shrubs.

LITERATURE REVIEW

I. Forest Grazing

Livestock grazing of forestlands has often met with criticism from the forest industry (Dutton 1953, Hedrick 1975, Sampson 1926). Part of the concern has been the result of past management of livestock in conifer regeneration sites. Heavy grazing by uncontrolled livestock often resulted in destruction of plantations due to excessive browsing and trampling of conifer seedlings (Hill 1917, Leiberg et al. 1904, Pearson 1983). Another reason for the high degree of skepticism towards livestock in forest plantations has been the lack of good examples of integrated management of forest lands for both livestock and timber production (Pearson 1983). Conflicts of interest and vigorous opposition by both the livestock industry and foresters towards integration of typically distinct land uses has compounded the problem (Adams 1978, Tustin and Knowles 1975).

Currently, there is growing awareness that livestock and timber can be integrated into compatible uses of the same land-resource area. Multiple land-use production systems incorporating livestock grazing and timber production have been shown to provide several benefits. In many forested areas, livestock grazing of herbaceous and woody vegetation in fuelbreaks, along roadsides, and within plantations have reduced fire risks (Burrows 1981, Ingram 1928, Monfore 1983, Throckmorton 1978). Sheep and cattle grazing in plantations have experienced adequate or improved weight gains, while at the same time improving conditions for tree growth (Leininger 1983, McKinnell 1975, Monfore 1983). In addition, improved livestock control measures in conifer plantations resulted in the protection and enhancement of nearby riparian and meadow areas (Monfore 1983).

In New Zealand and Australia, initial interest in the concept of forest farming using Pinus radiata came from forest companies interested in the advantages of early agricultural returns, easy stand access, simpler stand management, and reduced fire risk (Tustin and

Knowles 1975). Agricultural interest was based on a desire to diversify farm production and reduce market and biological risk. Agroforestry systems were seen as a means of combining traditionally distinct land uses, with the expectation that the net financial return would be higher per unit area than from either forestry or agriculture alone (Tustin et al 1979).

Several studies have shown livestock grazing in forests to be compatible with conifer regeneration (Hall et al. 1959, Kosco and Bartolome 1983, Krueger 1983, Leininger 1983, McLean and Clark 1980). The degree of success in combining these two land uses was highly dependent upon application of good forest and livestock management principles, agreement on land-use objectives, and complete cooperation between all private landowners, livestock operators and public agencies involved (McDonald 1986, Monfore 1983).

One possible negative effect of livestock grazing in plantations has been levels of browsing and trampling which reduce tree survival and growth (Cleary 1978). Excessive stress on seedlings during the establishment period decreases the success of reforestation. In the past, browsing and trampling of tree seedlings resulted from unsuitable application of basic livestock management principles (Adams 1978, Leininger 1983, Sampson 1926). Stoddard, Smith and Box (1975) discussed the following factors influencing grazing behavior: forage availability and livestock preference, season of grazing, intensity of use, and livestock control. Forest grazing studies indicated understanding the relationships between these factors and how to apply them in a forested ecosystem minimizes conflicts between grazing and wood production.

Leininger (1983) working in young Douglas-fir plantations in the Oregon Coast Range, demonstrated conifer seedlings were relatively unpalatable to livestock. Diet samples collected from sheep grazing in the study area indicated a preference for grasses in the spring, followed by an increase in forb and browse intake as the summer drought progressed and grass palatability decreased. Douglas-fir intake levels were very low, indicating avoidance of this plant by the sheep. Although livestock generally find conifers unpalatable, elimination of forage species, through site preparation or overgrazing, may result in greater browsing of trees (Black and Vladimiroff 1963, Cassidy et al. 1955, Throckmorton 1978).

Livestock browsing of conifer regeneration is greatest on the current year's early succulent growth (Hill 1917, Leininger 1983). For this reason, it is generally recommended grazing occur during periods before or after bud break (Black and Vladimiroff 1963, Gillingham et al 1976, Leininger 1983), and after seedling establishment, when young trees are less susceptible to injury (McDonald 1986, Throckmorton 1978). Timing of grazing has also been shown to be critical when attempting to optimize control of competing vegetation in young plantations. Monfore (1983) found grazing when grass phenology was vegetative kept the forage in the more palatable vegetative stage longer into the grazing season. When maximum control of competing vegetation was the goal, grazing was more effective if applied early in the growing season, and beginning the first year of the plantation (Clark and McLean 1975, Rhodes 1983).

Controlled livestock grazing in conifer plantations, under light and moderate grazing intensities, does not appear to adversely affect conifer regeneration (Hall et al 1959, Ingram 1928, Kosco and Bartolome 1983, Krueger 1983, Smith et al 1958, Tisdale 1960). Heavy rates of grazing, especially in high animal concentration areas, caused the greatest damage to seedlings in central Colorado (Currie et al 1978, Tisdale 1960). However, high intensity, short duration grazing by sheep bands has been used successfully for site preparation and vegetation control before and after conifer seedling establishment (Beveridge et al 1973, Throckmorton 1978). Moderate and heavy livestock grazing before and after conifer seedfall, proved to be suitable with germination and establishment of coniferous forest species (Pearson 1934, Tisdale 1960). Generally, light grazing intensities are recommended during the first year of a plantation, when conifer seedlings are most susceptible to browsing and trampling injury (Batini et al 1983, Cassidy et al 1955).

A recurrent theme throughout the forest grazing literature has been the importance of proper livestock control to the success of any forest grazing program. Severe grazing damage to conifer seedlings is often due to uncontrolled animal numbers, leading to overgrazing, shifting of livestock food preference, and subsequently browsing and trampling of seedlings (Eissenstat et al 1982, Hill 1917, Leiberg 1904, Krauch 1936). Plantation grazing generally requires more intensive management of animals to achieve the dual goal of maximum control of competing vegetation, while keeping browsing and trampling to a minimum (McDonald 1986, McLean and Clark 1980).

Eissenstat et al (1982) reported uncontrolled livestock grazing in first year Douglas-fir plantations resulted in trampling damage and a subsequent decrease in conifer survival. Improved control of animals the second and third year decreased trampling to a negligible level. Monfore (1983) found livestock damage to lodgepole pine (Pinus contorta) and ponderosa pine (Pinus ponderosa) seedlings in southwestern Oregon was decreased with application of more intensive livestock control measures. This included timing grazing to palatable stages in the vegetative phenology of grasses, increasing animal numbers, and intensifying livestock control and movement to facilitate effective herd distribution. Suggested techniques for improving livestock control include a herder for sheep (Leininger 1983), a full time rider (Monfore 1983), an adequate, properly located water supply (Currie et al 1978, Monfore 1983), and fencing (Monfore 1983).

Browsing and trampling does not directly imply reduction in survival potential of conifers. Although

44 percent of the Douglas-fir trees in a first year plantation were browsed by sheep, most of the browsing was classified as light and did not interfere with establishment of Douglas-fir (Black and Vladimiroff 1963). After 3-4 years of age, ponderosa pine seedlings were less susceptible to the effects of browsing and trampling than 1-year-old seedlings (Leiberg 1934). Some studies have reported damage reducing seedling growth was a result of repeated trampling rather than browsing (Ingram 1931, McLean and Clark 1980).

II. Vegetation Management in Conifer Plantations

Optimum survival and growth of conifer seedlings in plantations is dependent upon effective control of woody and herbaceous vegetation competing with trees for limited site resources such as light, moisture and nutrients (Cleary et al 1978). Vegetation management has been shown to enhance growing conditions, favoring early site dominance by the desired crop tree at the expense of undersireable vegetation, ultimately bringing the timber crop to maturity in the shortest possible time (Cleary et al 1978, Newton 1967a).

Disturbances, such as overstory removal and site preparation in conifer regeneration sites, tend to result in the encroachment of pioneer or successional vegetation. The herbaceous and woody components of these early plant communities often exhibit vigorous juvenille growth characteristics far exceeding those of planted or naturally regenerated conifer seedlings (Cleary et al 1978).

Shrubs have been shown to generally be deeper rooted than grasses, allowing removal of moisture from lower depths in the soil profile (Cleary et al 1978, Peterson and Newton 1983). Some hardwoods, particularly red alder (*Alnus rubra*), display robust juvenille growth inabling them to dominate a reforestation site quickly (El-Hassan 1967). Snowbrush (*Ceanothus velutinus*) suppressed Douglas-fir tree growth by 50 percent if not controlled in the first 5 years (El-Hassan 1967). Removal of both snowbrush and forbs resulted in the greatest increases in stem diameter and volume growth of 5-year-old Douglas-fir trees (Zavitkowski et al 1969). In a long term study, manual and chemical release of balsam fir (*Abies* *balsamea*) seedlings from shrub competition produced significantly greater volume growth than control plots, 32 years later (MacLean and Morgan 1983).

Snowbrush and greenleaf manzanita (*Arctostaphylos patula*) growing in a montane chapparal site in the northern Sierra Nevada, were able to withstand and recover from lower xylem pressure potentials than white fir (Conard and Radosevich 1981). Snowbrush maintained photosynthetic rates 1.5 to 2 times greater than those for white fir and greenleaf manzanita through the summer drought. Water stress inhibited photosynthesis, and subsequently growth of white fir. In laboratory studies, snowbrush was better adapted to high temperatures than white fir.

Cleary (1978), when discussing the importance of vegetation management in reforestation, felt the quantity of available soil moisture to be the most important factor to consider when evaluating the effects of vegetation competition. Competition studies have established soil moisture availability as the primary factor limiting growth in coastal Douglas-fir plantations (Cole and Newton 1986), and in young white fir (*Abies concolor*) stands (Conard and Radosevich 1982). In the Oregon Coast Range, Preest (1975) correlated increases in soil moisture with increases in Douglas-fir seedling water potential. A single first year control treatment of herbaceous vegetation increased tree volume 82 percent over the control in five years, with positive differences in tree survival. Chemical weed control in a mixed grass-forb community increased needle water potential, nutrient uptake, and growth of Pinus radiata seedlings (Sanandan Nambiar and Zed 1980). Percentage plant cover and species composition of weeds were practical indicators of the level of moisture stress to be expected in young radiata pine plantations. Newton (1964), in search of a quantitativce measure of vegetation influence on conifer survival and growth, found the rate of soil moisture depletion to be a direct function of the amount of herbaceous vegetation present on the site.

Grasses have establishment and growth characteristics inabling them to preempt limited site resources before conifer seedlings (McDonald and Tappeiner 1986). Several studies have demonstrated how grasses deplete moisture from the rooting zone of young conifers early in the growing season, before seedlings have completed their normal growth.

In a greenhouse study, Lane and McComb (1948) saw the rapid moisture absorption and lower wilting percent exhibited by grass (Bromus inermis), coupled with the ability of grass roots to remain dormant in the soil at the wilting point while trees die, as important factors to consider when establishing plantations on grassy sites. Larson and Schubert (1969) found perennial grasses growing in common with ponderosa pine seedlings to be much more drought tolerant than the pines. The grasses depleted soil moisture faster and to lower depths than the pine, and displayed a faster recovery rate from drought once favorable soil moisture conditions resumed. Grass roots grew faster than pine roots, inabling them to occupy a given volume of soil sooner. Consequently, root and top growth was significantly greater for pines growing without competition from grass. Perennial ryegrass (Lolium perenne) root growth and nutrient uptake characteristics have been shown to enhance its ability to compete for moisture and nutrients in surface soil horizons (Messenger 1976).

Preest (1973) monitored soil moisture changes during the summer under herbaceous communities within a young Douglas-fir plantation. In a heavy grass treatment, high demands on soil moisture were made in the upper profile early in the season, while demands on the lower profile were moderate. A forb-annual grass community was the most demanding, causing early season, heavy withdrawal of moisture in the upper profile, and maintaining moisture depletion in the lower profile.

Several methods or combination of methods have been used to provide adequate control of competing vegetation in plantations during site preparation, or as release treatments. Complete eradication of understory vegetation has not been necessary or desireable, since some plant cover maintains soil stability and nutrient capital (Cleary et al 1978, Newton 1973).

Mechanical scarification for controlling brush or hardwoods, though suitable on gentle slopes, has been costly and in some situations resulted in the immediate establishment of pioneer communities (Newton 1973, Newton and Roberts 1979). Manual slashing or scalping generally has given only short term gains in vegetation suppression, since slashing often resulted in resprouting of shrubs (Hobbs and Wearstler 1985, Newton and Roberts 1979). Hand slashing is costly and can be dangerous.

Prescribed burning to remove slash from plantations and retard the establishment of understory vegetation has been widely used in the Douglas-fir region (Newton 1984). However, air quality control regulations frequently limit the use of burning. In some forest types fire stimulates the germination of dormant brush seeds in the soil, resulting in a dense stand of brush seedlings 1-3 years following prescribed burning (Gratowski 1961).

Herbicides have been the primary tool for conifer release on non-federal forest lands. When used properly, chemicals can be powerful tools for manipulating plant communities, offering specific control, low to moderate cost, and low risk (Newton 1967b, Newton and Roberts 1979). Following application of the appropriate herbicide, vegetation changes were more gradual (Newton 1973). Nevertheless, use of herbicides in forests has aroused considerable public concern over possible health risks. Recent court decisions have banned the use of herbicides on public forest lands in the Pacific Northwest.

Limitations on the use of herbicides in public forests has heightened interest in plantation grazing as another vegetation management tool (Leininger

1983). Pearson (1934) proposed viewing livestock grazing in forest lands as part of the silvicultural program where timber is the primary crop. Recent investigations have evaluated the application of livestock grazing as a silvicultural tool for enhancing conifer regeneration and growth (Kosco and Bartolome 1983, Leininger 1983, Monfore 1983).

III. Livestock Grazing as a Vegetation Management Tool

Several studies have reported survival and growth response of conifers to release treatments using livestock grazing. In northeastern Oregon, survival of four planted coniferous species was similar between cattle grazing, wildlife grazing, and dual grazing treatments (Krueger 1983). The dual grazing treatment resulted in significantly greater height growth of Douglas-fir and ponderosa pine trees 13 years after planting. Sheep grazing in Oregon white oak (*Quercus garryana*) woodlands produced greater height growth increment for Douglas-fir seedlings in grazed plots as compared to ungrazed plots, and continued three years after grazing stopped (Hedrick and Keniston 1966).

Leininger (1983) studying sheep grazing in Oregon's Coast Range, found survival of Douglas-fir regeneration to be unaffected by grazing in 2, 4 to 6-year-old plantations. Annual height increment was unaffected by grazing in the older plantations, whereas mean annual diameter increment was higher in the grazed units. Height and mean diameter increment of Douglas-fir seedlings in a 2-year-old plantation grazed in May were reduced due to heavy browsing by sheep.

Livestock grazing has proven to be an effective means of controlling herbaceous and woody vegetation invading conifer plantations (Kosco and Bartolome 1983, Leininger 1983, Monfore 1983). Controlled grazing of Douglas-fir cutover land resulted in 70 and 80 percent utilization of forbs and graminoids, respectively (Ingram 1928). Utilization by livestock ranged from 50 to 95 percent on new burns, and 10 to 25 percent in established stands of longleaf pine (<u>Pinus palustris</u>) (Smith et al 1958). Sheep grazing in Douglas-fir plantations effectively reduced both total and mean brush net growth present in the fall ($p<.01$) compared to ungrazed treatments (Rhodes 1983).

Hall et al (1959) and Hedrick and Keniston (1966) found more favorable soil moisture conditions on grazed portions of Douglas-fir plantations established in the Oregon white oak type. In the Oregon Coast Range, a 2-year-old plantation had more available soil moisture in the top 15cm of soil in the ungrazed treatments as compared to treatments grazed in May. Five percent more soil moisture was present in the 75-90cm depth of grazed as compared to ungrazed areas of the same plantation. Black and Vladimiroff (1963) indicated no differences in soil moisture content in grazed and ungrazed treatments.

Livestock grazing, through selective utilization of available forage, has been shown to influence successional trends in forested sites following logging and site preparation. Grazing management in transitional forest ranges differs from traditional range management aimed at maintenance of secondary vegetation permanantly suited to grazing use (Ingram 1931). Livestock grazing in forests and plantations is generally employed to reduce fire risk or vegetation competition through suppression of weedy plants. Sheep grazing in Washington clearcuts enhanced the uniformity of grazing and the level of utilization as succession advanced and the proportion of palatable plants increased on the site (Ingram 1931). Both Isaac (1940) and Ingram (1931) reported at least 50 percent utilization of fireweeds, the most dominant plant in the understory, in the first few years following site disturbance. As clearcut age increased, the proportion of palatable perennial species declined.

In northeastern Oregon, continuous heavy grazing by both cattle and big game resulted in retrogression of the understory (Krueger and Winward 1974, Krueger 1983). Grazing by wildlife alone did not significantly influence frequency of perennial grasses and sedges. Big game grazing alone or in conjunction with cattle grazing significantly reduced cover and frequency of browse. Plant species were differentially influenced by each treatment or combination of treatments.

IV. Seeding of Forages into Plantations

The practice of seeding forages into conifer plantations for use alone, or in conjunction with livestock grazing, as a vegetation management tool has been based on two underlying assumptions. First, palatable forages will focus the grazing animals attention on the competing vegetation and away from the trees, resulting in higher and more uniform utilization. Second, seeded herbaceous vegetation may retard encroachment of woody plants which can be more competitive with established conifer seedlings (McDonald 1986).

In Douglas-fir plantations, seeding with palatable forage species produced the highest and most uniform levels of utilization (Ingram 1928, Miller and Krueger 1976). In northeastern Oregon, seeded grasses accounted for 55 percent of cattle diets (Miller and Krueger 1976). Studies in Australia found less animal damage to occur in plantations where green-clover dominant pasture was available (Anderson and Batini 1979).

Seeding of perennial grasses in forested areas reduced survival, density and growth of brush seedlings that would otherwise occupy a site (Schimke et al 1970, Schultz et al 1955). Grasses and legumes seeded into Douglas-fir plantations following slash burns significantly reduced the frequency and cover of red alder when measured five years later (Klinger 1982). Krueger (1983) concluded the principal effect of grass seeding was to significantly reduce the abundance of resident graminoids and large and abundant forbs.

Shrub response was not affected by seeding alone. Grass treatments 5 years after ponderosa pine seedlings were planted resulted in statistically better height and diameter growth of the pines (McDonald 1986).

McDonald (1986) recommended grass seeding to control woody shrub invasion in conifer plantations should not take place until past the establishment period (i.e. 5 years). Others have found seeding forages, alone or in combination with livestock grazing, can be compatible with conifer regeneration in the early years of plantation existence (Klinger 1982, Clark and McLean 1979). Early forage seeding and livestock grazing has provided release of young radiata pine from competition (Anonymous 1975, Beveridge et al 1973, Farnsworth et al 1976, Gillingham et al 1976).

Survival and height growth of conifer seedlings was not significantly different in grass seeded areas as compared to unseeded areas, both grazed by cattle (Krueger 1983). Tree mortality induced by cattle grazing was not different between seeded grazed and unseeded grazed units (McLean and Clark 1980).

Cole and Newton (1986) determined grasses seeded into plantations in the Oregon Coast Range competed with Douglas-fir seedlings primarily for soil moisture and decreased seedling growth. Eissenstat and Mitchell (1983) working in Idaho, reported both predawn and midday water potential of Douglas-fir seedlings were significantly reduced by a seeded grass-legume treatment in a 2-year-old plantation. Although seeded grasses significantly decreased Douglas-fir diameter, shoot growth and height, Douglas-fir water potential could not be related to the growth parameters measured. The authors hypothesize water may not be the only limiting factor, nor the most important factor limiting Douglas-fir performance in this habitat type.

Ponderosa pine seedling establishment in grass was better when planted or directly seeded in conjunction with grass the first year after the site was burned (Baron 1962). The influence of grass on pine regeneration was species dependent. Grass seeding rates did not affect lodgepole pine germination or survival, however, increasingly higher grass seeding rates significantly reduced pine total biomass and early height growth (Clark and McLean 1979).

CHAPTER I

INFLUENCE OF LIVESTOCK AND WILDLIFE ON ESTABLISHMENT OF CONIFER PLANTATIONS IN SOUTHWEST OREGON

Mabel Alejandro-Castro

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Influence of Livestock and Wildlife on Establishment of Conifer Plantations in Southwest Oregon

Abstract

Establishment of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and ponderosa pine (*Pinus ponderosa* Dougl.) seedlings with controlled cattle grazing and seeding of palatable forages, was monitored for two years following planting on two 10ha study sites. Site 1 was tractor logged and broadcast burned, and Site 2 had tree overstory removed by machine scarification, followed by piling and burning of debris. Sites were planted in the spring of 1985 with a 5:1 ratio of Douglas-fir to ponderosa pine. Seedling growth and survival were monitored from 1950 permanently marked trees. Measurements during 1985 and 1986 indicated that Douglas-fir survival and growth did not differ between the silviculture-control, seeded-ungrazed, seeded-grazed, and native-grazed treatments on each site. For ponderosa pine, second year survival was significantly lower ($p \leq 0.05$) in the seeded-grazed treatment on Site 2, and highest in the

native-grazed treatment on Site 1. Assessment of causal factors contributing to conifer mortality indicated that severe frost damage the first growing season affected more trees in the seeded treatments as compared to the unseeded treatments. In general, frost damage dramatically increased Douglas-fir mortality and affected the highest percentage of trees on the sites (43.6 percent). During the second winter, Douglas-fir seedlings were heavily browsed by elk (57.7 percent of trees on Site 1, 23.1 percent on Site 2). However, elk selectively browsed healthier seedlings which were not affected by the frost. This resulted in relatively low mortality for seedlings influenced by this variable. Although livestock browsing and trampling increased Douglas-fir mortality, their potential influence was minimized by a controlled grazing program maintaining browsing at 2.6 percent, and trampling at 6.0 percent during both years of the study.

Introduction

Many environmental factors, often beyond the control of the silviculturist, play key roles in determining the success or failure of reforestation programs. Little information is known on how environmental variables such as frost, animal browsing and trampling, and drought influence the survivability of conifer seedlings.

The study described in this paper was part of a research project designed to evaluate the ability of controlled cattle grazing, in combination with seeding forages, to reduce understory competition in young conifer plantations. Recent investigations suggest that when animal numbers and season of use are carefully managed, livestock grazing can be compatible with the objectives of forest regeneration (Kosco and Bartolome 1983, Krueger 1983, Leininger 1983). However, concern exists over livestock impacts, namely browsing and trampling, which may nullify any potential benefits to the seedling from grazing, particularly when grazing begins the first year of a plantation (Cleary 1978). Seeding palatable forages into plantations, for brush control and to improve livestock utilization, has also been controversial when implemented prior to conifer establishment (McDonald 1986).

In this study, interpretation of Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco.) survival and growth response to grazing treatments was complicated by two environmental factors- severe frost and heavy browsing by elk. In the southwestern portion of the Cascade Range in Oregon, the combination of a xeric climate, and aggressive successional vegetation occupying new plantations, increases the need for vegetation management techniques designed specifically for this area.

The goal of this study was to evaluate the influence of cattle grazing and forage seeding, apart from frost and wildlife browsing, on Douglas-fir and ponderosa pine (Pinus ponderosa Dougl.) establishment in southwest Oregon. The objectives were (1) to monitor conifer survival and growth, (2) to assess browsing and trampling levels by both cattle and wildlife, and (3) with the use of a binomial response model, determine the relative influence of livestock activities, wildlife browsing, and frost damage on conifer mortality.

Study Area

The study area is located eight miles northeast of Butte Falls, Oregon on land administered by the Medford District of the Bureau of Land Management. This region is the southern-most portion of the Western Cascade Physiographic and Geologic province, which developed from volcanic flows and pyroclastics (Franklin and Dyrness 1973). Elevation is 987m and characterized by a mediterranean-type climate with a mean annual precipitation of 88.9cm occuring as rain in the fall and spring, and snow and rain in the winter (deMoulin et al 1975). Average seasonal temperatures range from -1°C in January to 18°C in July. Summers are typically hot and dry.

Douglas-fir is the most abundant conifer in the mixed-conifer vegetation zone typical of mid-elevations in the southwestern flank of the Cascades (Franklin and Dyrness 1973). Sugar pine (Pinus lambertiana), ponderosa pine and incense cedar (Calocedrus decurrens) occur as scattered individuals, and white fir (Abies concolor) is present as seedlings and saplings. Hardwoods include vine maple (Acer macrophyllum), pacific madrone (Arbutus menziesii), and chinquapin

(*Castanopsis chrysophylla*). Primary shrub and herbaceous components within mature stands are California hazel (*Corylus cornuta* var. *californica*), creek dogwood (*Cornus nutallii*), oregongrape (*Berberis nervosa*), western yew (*Taxus brevifolia*), trailing blackberry (*Rubus ursinus*), oceanspray (*Holodiscus discolor*), and deerfoot vanillaleaf (*Achlys triphylla*). Blue wildrye (*Elymus glaucus*) is by far the most abundant grass in stand openings, with lesser amounts of foxtail fescue (*Vulpia megulara*) and Kentucky bluegrass (*Poa pratensis*).

Soils in the study area are represented by the Freezener and Geppert soil series, with the shallower Geppert soils occuring on ridge tops, and the deeper Freezener occupying side slopes (deMoulin et al 1975). Soils in the Freezener series (classified as mixed, mesic Ultic Haploxeralfs) have deep (102-152cm), well-drained profiles formed from basic igneous rock. These soils have dark reddish brown gravelly loam A horizons, and reddish brown silty clay Bt horizons. The Geppert series (classified as loamy-skeletal, mixed, mesic Dystric Xerochrepts) consists of moderately deep (50-100cm), well-drained soils formed from volcanic breccia or andesite. They have dark reddish brown cobbly clay loam A horizons, and dark reddish brown cobbly clay loam B horizons. Both soils have a high frost-heave potential.

Treatments as described in the methodology section were applied on two adjacent sites. Slopes ranged from 5 to 25 percent on both sites. Site 1 which has south to southwest, and west to northwest exposures, originally supported a second growth mixed-conifer stand. Douglas-fir was the dominant conifer in this stand and the associated overstory and understory vegetation was similar to the mixed-conifer vegetation previously described. Tractor logging produced a 9.7ha clearcut in June, 1984. Site preparation was accomplished by broadcast burning of slash in early October, 1984. Site 2 was occupied by a 20-year-old ponderosa pine plantation with southeast, west and northwest aspects. The understory vegetation was dominated by perennial and exotic annual grasses and trailing blackberry. The plantation was in poor condition due to the use of pine stock not appropriate for this environment, and severe soil compaction caused by winter logging in the past. In August, 1984, a 10.5ha unit was scarified and piled, followed by ripping of compacted soil layers. Slash piles were burned in the fall. In the winter of 1985, both sites were planted to a 1.8m x 1.8m spacing (2200-2500 trees/ha) of 2-0 bare root Douglas-fir and ponderosa pine seedlings at a ratio of 5 Douglas-fir to 1 ponderosa pine.

Methods

Treatment Application and Grazing Management

Treatments were applied to both Site 1 and Site 2 in a randomized block design with two blocks per site and one replication of each treatment in each block. Four treatments were applied to both Site 1 and Site 2:

(1) Silviculture-control (SC): Currently available silvicultural methods were used to control vegetation competition. A treatment was considered unnecessary the first year (1985), with a paper mulch application utilized in early spring, 1986. No grazing occurred in this treatment.

(2) Native-grazed (NG): Livestock grazing alone was used to control competition with successional

vegetation naturally invading the site. The Native-grazed treatment on Site 1 was not grazed in 1985 or 1986 due to lack of palatable forage for cattle, suggesting this treatment was basically a control.

(3) Seeded-ungrazed (SU): Grass-legume mix seeded and no grazing. This was viewed as the high competition treatment.

(4) Seeded-grazed (SG): Seeded with the same grass-legume mix, but including livestock grazing in 1985 and 1986.

The SU and SG treatments were seeded in the fall of 1984, soon after prescribed burning of Site 1. Justification for these treatments was based on the assumption that transformation of understory vegetation to highly palatable forage would curtail enchroachment of woody vegetation, and focus grazing on forage, thereby increasing utilization and ultimately control of competing vegetation. The criteria for selection of the desired grass-legume mix were high palatability and/or the ability to establish rapidly on similar sites. The seeding mixture was applied at a ratio of 14.6 kg/ha and included perennial ryegrass (<u>Lolium perenne</u>, `Linn' variety at 1.7 kg/ha), orchardgrass

(*Dactylis glomerata*, `Potomac' variety at 5.6 kg/ha), white clover (*Trifolium repens*, `New Zealand' variety at 1.7 kg/ha), and subterranean clover (*Trifolium subterraneum*, `Mt. Barker' variety at 5.6 kg/ha). Inadequate establishment due to frost heaving and lack of winter and spring precipitation called for a second seeding in March, 1985, using orchardgrass alone at a rate of 14.6 kg/ha.

The effectiveness of a release treatment is dependent upon appropriate timing of the procedure, i.e. before soil moisture is depleted by competing vegetation (Newton 1967). It then follows that the success of the grazing release treatments should be dependent upon proper timing of grazing. Therefore, grazing treatments were applied to encourage the highest utilization and greatest reduction in vigor of available forage. Grazing management criteria were: (1) Early grazing to decrease soil moisture depletion and to graze when grass phenology was vegetative and palatable. Defoliation at this time coincides with the period of active growth and depletion of carbohydrate stores, resulting in reduction of vigor (Moser 1977). (2) To graze at a high intensity (approximately .2

ha/AUM), and (3) to graze significant levels of regrowth.

To accomplish vegetation management with cattle, put-and-take grazing (Wheeler et al 1973) was utilized, where stocking rate was varied as frequently as the availability of the forage required. During each grazing period, removal of animals from pastures was based on a reduction in available forage to approximately 5cm stubble height of grasses, and increasing levels of livestock trampling. In 1985, both single cows and cow-calf pairs were used, while only pairs grazed in 1986. To facilitate proper livestock control, a 1.2m high barbed-wire fence was established around the perimeter of each site. Fencing of individual treatments was accomplished with portable electric fencing during grazing periods. A description of pastures and animal use is provided in Table I.1.

Sampling Procedures

Information on survival, growth, browsing and trampling was generated from sample trees located within permanently marked circular plots established after planting in 1985. Fifteen circular plots with a

Table I.1. Description of pastures, cattle numbers, and grazing use on Site 1 and Site 2, 1985 and 1986.

Site	Treatment	Year	Area Grazed (ha)	No. of Grazing Periods	Animal Nos. per Grazing Period	Total Animal Days of Grazing
1	Seeded-Grazed	1985	2.8	2	8, 9	44
		1986	2.8	2	29, 9	156
2	Native-Grazed	1985	5.3	1	4	20
		1986	5.3	1	14	80
	Seeded-Grazed	1985	5.3	1	8	20
		1986	5.3	2	10, 6	95

3.6m radius were systematically located within each treatment replication. All trees present within the plots were mapped by measuring the distance of each tree from plot center (Husch et al 1972). This resulted in a total of 1950 sample trees, or approximately 120 trees per treatment replication. Spring and fall tree surveys in 1985 and 1986 produced information on conifer survival and wildlife browsing and trampling. Livestock browsing and trampling were monitored before and after each livestock grazing period. Removal of terminal or lateral branches or needles constituted browsing by animals. Trampling was defined as mechanical damage causing removal of tree bark and exposure of the cambium (Eissenstat et al 1982).

Two consecutive nights of below freezing temperatures in late June, 1985 when seedlings were actively growing, resulted in heavy mortality of seedlings the following winter. Sample trees were surveyed within three weeks of the frost to establish a record of percentage of trees damaged. Ponderosa pine seedlings were not affected by the frost.

During fall surveys in 1985, calipers were used to determine tree diameter 2.5cm above the root crown. As a result of the frost, insufficient tree numbers were present within sample plots in several treatment replications, preventing estimation of tree diameter in 1986.

Experimental Design and Analysis

Analysis of Variance

Analysis of variance was used to test treatment and site differences in livestock browsing and trampling, wildlife browsing and trampling, and conifer survival and growth (Snedecor and Cochran 1980). A probability value of $p<0.05$ was used throughout the analysis to test significance of F values. Comparisons of treatment means were tested using the Newman-Keuls method, where means are significantly different at $p<0.05$ (Snedecor and Cochran 1980). Lack of planted ponderosa pine seedlings in one block of treatments on Site 1 prevented testing of treatment by site interactions for survival, growth and browsing and trampling data.

Chi-square Test of Independence

Visual observations of Douglas-fir seedlings following the June, 1985 frost indicated the incidence of frost damage may be greater in some treatments than in others. A two-way (4 x 2) contingency table was used to determine whether frost damage was a random occurance (Snedecor and Cochran 1980). The analysis compared the proportion of frost to no frost in each treatment. The chi-square statistic, comparing observed and expected frequencies, was used to test the independence of the two variables.

Binomial Response Model

One objective of this study was to determine the potential impact of livestock browsing and trampling on conifer survival. Interactions with frost damage and elk browsing prevented a direct measure of conifer mortality due to livestock activities alone. A binomial response model was developed to describe the probability of Douglas-fir and ponderosa pine mortality for a combination of independent variables- i.e. frost damage, wildlife, and livestock impacts (McCullagh and Nelder 1983). The binomial response model was needed to address the following questions:

1. What was the probability of mortality for Douglas-fir or ponderosa pine seedlings browsed or trampled by cattle? ..by elk?

2. If a Douglas-fir seedling was frost damaged, what was its chance for survival?
3. What was the affect of combinations of these factors on conifer mortality?

The binomial response function is approximated by the binomial distribution as follows:

$Yi \sim B(mipi)$, for $i=1,.,.,.,n$, where

Yi= a binary dependent variable, in this case mortality,

mi= the number of observations for each ith combination of independent variables,

pi= the probability of mortality for each ith combination, and

n= the total number of combinations of independent variables.

The independent variables of interest were livestock browsing, livestock trampling, wildlife browsing, wildlife trampling at four levels (0=no, 1=in 1985, 2=in 1986, 3=both years), frost damage at two levels (0=no,1=yes), and treatment (at four levels). Predicted probability of mortality was based on information for the independent variables, collected from individual trees in permanent plots located within each treatment.

An optimum subset of predictor (independent) variables was derived using a backward stepwise logistic regression which began with a full set of variables and eliminated the worst ones, one at a time, until all remaining were necessary (McCullagh and Nelder 1983). The predicted proportion of mortality followed the logistic function: P(mortality)= exp (U)/(1 + exp(U)), where U= a linear function of one or more independent variables (Neter et al 1983). At each step in the process, estimates of coefficients for the independent variables in the binomial response function were produced. The improvement chi-square tested the hypothesis that the term removed significantly improved prediction by comparing the fit of the present model to the fit of the previous model. The chi-square Goodness of Fit statistic is not reliable when the expected frequency of mortality for a particular combination of independent variables (i.e. mi) is less than five observations. Expected frequencies of mortality which included livestock browsing and trampling, and wildlife browsing of trees in 1985 were often less than five. A better measure of the goodness of fit of the model was the Pearson statistic (rp), a standardized residual, where rp= [(observed proportion dead)-(predicted probability of mortality)]/ standard error of the residual (McCullagh and Nelder 1983). For each combination of independent variables, the model was determined to be a good fit to the data if rp was less than 1.96 (i.e. the 95 percent confidence interval).

Results and Discussion

Analysis of Variance

The goal of this study was to assess the ability of early, intense grazing by cattle to enhance conifer establishment by controlling understory vegetation in young plantations. Related work in this research (see Alejandro-Castro 1988) determined selective grazing by cattle, in conjunction with seeding of palatable forages (i.e. SG treatment), improved understory utilization by cattle and enhanced the water relations of Douglas-fir seedlings in 1986, as compared to seedlings in the NG (native-grazed) treatment, and the SU (seeded-ungrazed) treatment. In this study, survival of Douglas-fir in 1985 and 1986, and diameter response in 1985 did not differ significantly between treatments.

Although ponderosa pine survival and diameter response were similar between treatments in 1985, survival response differed between treatments in 1986 (Table I.2). On Site 1, pine survival was greater in the NG treatment, not grazed in 1985 or 1986, than in the other treatments which did not differ. On Site 2, trees growing in the SG treatment had lower survival of ponderosa pine than trees growing in the SC (silviculture-control), NG, and SU treatments which had similar levels of survival.

Survival (Table I.2) and mean diameter of Douglas-fir and ponderosa pine were significantly higher on Site 1 as compared to Site 2 in 1985 and 1986. Mean diameter of Douglas-fir was greater on Site 1 (7.3 ± 0.4mm) than on Site 2 (6.3 ± 0.2mm). Ponderosa pine survival was also greater on Site 1 (7.2 ± 0.2mm) as compared to Site 2 (6.5 ± 0.2mm).

These site differences may be related to the higher herbaceous cover and generally drier conditions (see Alejandro-Castro 1988) present on Site 2. Also, Minore (1986) studying differences in Douglas-fir growth on sites receiving pile and burning versus broadcast burning, determined seedlings on pile and burn sites had significantly lower height growth.

Table I.2. Mean percent survival (and standard error) of Douglas-fir and ponderosa pine seedlings in the first and second year of the plantations on Site 1 and Site 2 in the following treatments: SC (Silviculture-control), NG (Native-grazed), SU (Seeded-ungrazed), and SG (Seeded-grazed).

Douglas-fir

1985	Site 1[2]	76.7 (1.86)
	Site 2	56.2 (2.57)
1986	Site 1[2]	43.8 (5.28)
	Site 2	32.9 (2.60)

Ponderosa pine[1]

1985	Site 1[2]	74.6 (5.48)	
	Site 2	69.9 (4.95)	
1986	Site 1[2,3]	61.1 (6.17)	
	SC	63.0 (13.83)	a
	NG	92.9 (4.61)	b
	SU	44.4 (6.73)	a
	SG	47.2 (6.85)	a
	Site 2[3]	50.9 (5.59	
	SC	56.8 (12.85)	a
	NG	53.9 (10.38)	a
	SU	58.8 (10.61)	a
	SG	31.5 (10.96)	b

1. Lack of complete treatment replication on Site 1 prevented formal test of treatment by site interaction for Ponderosa Pine.

2. Site means are different at $p \leq 0.05$.

3. Treatment means followed by similar letters are not significantly different at $p \leq 0.05$. A grazing treatment was not applied in the Native-grazed (NG) treatment on Site 1 in 1985 or 1986.

Controlled cattle grazing resulted in minimal levels of browsing and trampling in grazed pastures. This is consistent with results from other plantation grazing studies where animal use has been carefully controlled (Kosco and Bartolome 1983, Leininger 1983). Livestock browsing and trampling values did not differ significantly between treatments or sites in 1985 or 1986 (Table I.3).

Levels of wildlife trampling were relatively low and did not vary between treatments or sites in 1985 and 1986 (Table I.3). Wildlife browsing in 1985 was similar between treatments and sites, generally confined to spring browsing of the low, lateral branches on seedlings.

In 1986, wildlife browsing was significantly higher on Site 1 as compared to Site 2. A greater percentage of palatable grasses established in the seeded treatments attracted elk to the study area in late fall of 1985 (Alejandro-Castro 1988). These seeded grasses were closely cropped by the elk all winter long. Visual observations indicated that while forage was available, browsing was kept in check. However, in November of 1985, an intermittent snow layer covering the grasses but not the trees, resulted

Table I.3. Summary of percentage of Douglas-fir and ponderosa pine seedlings browsed or trampled by livestock or wildlife in 1985 and 1986. Values are means averaged over both sites (except for wildlife browsing in 1986).

	Browsing (Percent)	Trampling (Percent)
Livestock 1985	2.6 $\pm$ 0.85	6.0 $\pm$ 0.63
1986	2.2 $\pm$ 0.69	6.0 $\pm$ 1.12
Wildlife 1985*	16.3 $\pm$ 0.97	1.1 $\pm$ 0.24
1986 Site 1**	57.7 $\pm$ 0.44	1.3 $\pm$ 0.30
Site 2	23.1 $\pm$ 0.48	

* Wildlife browsing and trampling data for 1985 were collected between April and October of 1985, and 1986 data were collected from November 1985 to September 1986.

**Sites were significantly different ($p \leq 0.05$).

in heavy browsing of Douglas-fir terminals and laterals. Measurements indicated 34 percent more wildlife browsing occuring on Site 1 than on Site 2 in 1986 (Table I.3).

Chi-square Test of Independence

The significant ($p<0.05$) chi-square test of independence determined frost damage was not a random event, being highly dependent upon the treatment a Douglas-fir seedling was growing in. Summer tree surveys in 1985 determined 43.6 percent of the Douglas-fir seedlings were affected by frost damage. Tests for each site separately and sites together follow the same trend with the proportion of seedlings frost damaged highest in the SU treatment, lowest in the NG treatment, and somewhere in between for the SC and SG treatments (Fig. I.1).

On Site 1, the apparently higher incidence of frost damage in the seeded treatments relative to the unseeded treatments may partially be explained by the role the seeded vegetation may have played in altering absorbtion of heat or retention of cold air near the ground surface. When the frost occured in late June, 1985, the ground surface on Site 1 was still black as a

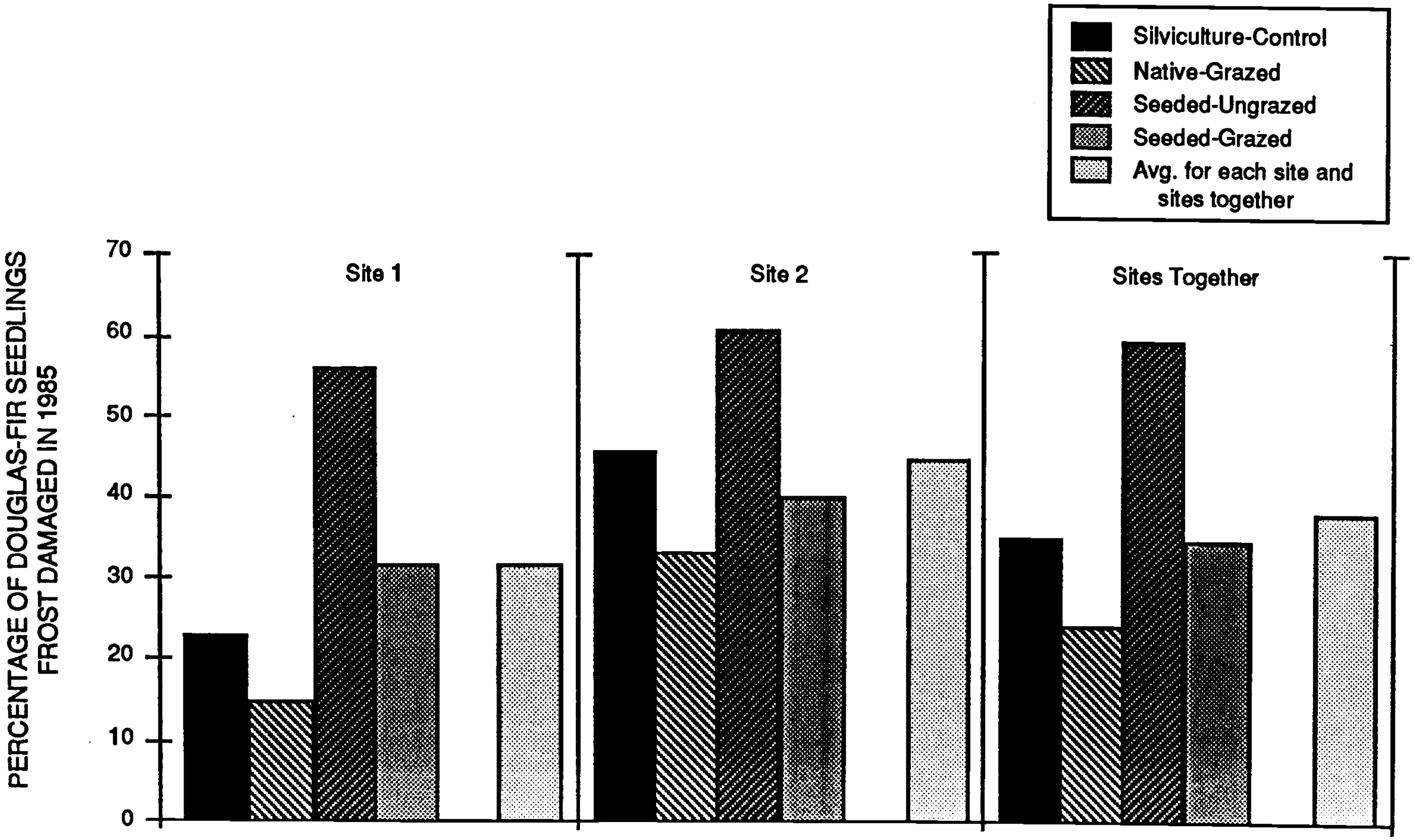

Fig. I.1. Percentage of Douglas-fir seedlings frost damaged in each treatment, for each site. A significant ($p \leq 0.05$) chi-square test of independence determined the incidence of frost damage was not a random event, affecting a higher percentage of trees in the seeded treatments compared to the unseeded treatments. The Native-grazed treatment on Site 1 received no grazing treatment in 1985 or 1986.

result of broadcast burning the previous fall. The low plant cover and higher percentage of black ground surface may have enabled these units to absorb more heat during the day, modifying the effect of cold air draining into the site at night. This would explain the overall higher proportion of frost in all treatments on Site 2 where herbaceous cover was greater. Regardless of the reasons why, because the incidence of Douglas-fir frost damage was dependent upon treatment, interpretation of survival and growth response to treatments is unclear and difficult.

Binomial Response Model

A direct measure of mortality specifically due to livestock impacts was undermined by interactions with frost damage and wildlife browsing. However, the binomial response model describes the individual and combined effects of frost damage, wildlife, and livestock impacts on Douglas-fir survival.

Douglas-fir mortality predicted by a binomial response function more closely approximated observed proportions of mortality when the following independent variables were included in the model: wildlife browsing by frost interaction, livestock trampling by frost interaction, livestock browsing and treatment. Table I.4 lists the coefficients used to determine predicted mortality for each combination of the independent variables in the model. Table I.5 lists the predicted mortality of Douglas-fir, the observed proportion, and the Pearson statistic (rp) for each combination of the factors in the data as summarized by the binomial response model. Figures I.2 to I.5 are comparisons of predicted mortality of Douglas-fir seedlings for some combinations of the independent variables.

Given no livestock browsing, livestock trampling, or wildlife browsing, the presence of frost damage increased mortality of Douglas-fir seedlings in 1986 in all treatments (Fig. I.2). For all combinations of independent variables in Figures I.2 and I.3, predicted mortality of Douglas-fir seedlings was lowest in the SC (Silviculture-control) treatment, followed by the NG (Native-grazed), SG (Seeded-grazed), and SU (Seeded-ungrazed) treatments. Predicted mortalities for the seeded treatments were apparently similar and generally larger than mortality for seedlings in the unseeded treatments.

Table I.4. List of independent variables and their corresponding coefficient used to determine predicted mortality of Douglas-fir for any combination of independent variables in the binomial response model.

Year	Independent Variable	Level of occurrence	Corresponding coefficient*
1986	Wildlife browsing	No	.5267
		1985	.4555
		1986	-.5373
		Both years	-.4448
	Frost damage	No	-1.5063
		Yes	1.5063
	Wildlife browsing X Frost	No	.0311
		1985	.2353
		1986	-.3213
		Both years	.0548
	Livestock trampling	No	1.1274
		1985	1.0527
		1986	-3.3738
		Both years	1.1937
	Livestock trampling X Frost	No	-1.0565
		1985	.14665
		1986	-5.3749
		Both years	6.2847
	Livestock browsing	No	2.4926
		1985	2.2105
		1986	-2.8248
		Both years	-1.8783
	Treatment	SC	-.6627
		NG	-.1384
		SU	.4267
		SG	.3745
	Constant		-3.4864

*Predicted Probability (mortality) = exp(U)/(1 + exp(U)), where U = a linear function of one or more of the independent variables in the model.

Table I.5. List of predicted mortality of Douglas-fir seedlings generated by the binomial response model for each combination of independent variables. The observed proportion is the percentage of sample trees actually affected by the given combination of factors. The Pearson statistic (rp), a standardized residual, is a measure of the goodness of fit of the model. The model is a good fit to the observed data if the absolute value of rp is less than or equal to 1.96.

INDEPENDENT VARIABLES*

Wildlife Browsing	Frost Damage	Livestock Trampling	Livestock Browsing	Treatment	Observed Proportion (%)	rp	Predicted Mortality (%)
0	0	0	0	SC	4.7	1.76	38.1
0	0	0	0	NG	4.5	1.95	51.0
0	0	0	0	SU	2.9	0.13	64.7
0	0	0	0	SG	3.1	0.27	63.5
0	1	0	0	SC	4.4	0.62	61.7
0	1	0	0	NG	3.6	0.70	73.2
0	1	0	0	SU	3.2	0.53	82.8
0	1	0	0	SG	1.2	1.03	82.0
1	0	0	0	SC	1.2	0.68	31.9
1	0	0	0	NG	0.6	0.07	44.2
1	0	0	0	SU	0.7	1.19	58.2
1	0	0	0	SG	1.8	0.73	56.9
1	1	0	0	SC	0.4	1.47	64.8
1	1	0	0	NG	0.3	0.98	75.7
1	1	0	0	SU	1.1	0.12	84.6
1	1	0	0	SG	0.4	1.90	83.9

* Possible levels of occurance for the independent variables: wildlife and livestock impacts at four levels (0=no, 1=in 1985, 2=in 1986, 3=both years); frost damage at two levels (0=no, 1=yes), treatment at four levels (SC=Silviculture-control, NG=Native-grazed, SU=Seeded-ungrazed, SG=Seeded-grazed).

Table I.5. (continued)

Wildlife Browsing	Frost Damage	Livestock Trampling	Livestock Browsing	Treatment	Observed Proportion (%)	rp	Predicted Mortality (%)
2	0	0	0	SC	9.8	0.27	23.2
2	0	0	0	NG	11.7	0.06	33.8
2	0	0	0	SU	4.3	0.23	47.4
2	0	0	0	SG	5.5	0.91	46.1
2	1	0	0	SC	5.0	0.67	28.1
2	1	0	0	NG	2.7	0.35	39.8
2	1	0	0	SU	5.8	0.37	53.8
2	1	0	0	SG	3.1	0.21	52.5
3	0	0	0	SC	2.4	0.01	18.6
3	0	0	0	NG	2.3	1.41	27.8
3	0	0	0	SU	2.2	0.04	40.4
3	0	0	0	SG	2.4	1.95	39.1
3	1	0	0	SC	1.1	0.23	38.5
3	1	0	0	NG	0.4	1.06	51.4
3	1	0	0	SU	2.2	0.73	65.0
3	1	0	0	SG	0.9	0.91	63.8
0	0	2	0	SG	0.2	1.70	59.2
0	1	1	0	SG	0.2	0.33	93.4
0	1	2	0	SG	0.1	0.01	0.1
2	0	1	0	SG	0.3	0.84	19.2
2	0	2	0	SG	0.4	0.84	41.6
2	1	1	0	SG	0.1	0.54	77.3
2	1	2	0	SG	0.1	0.01	0.1
3	0	1	0	SG	0.1	0.42	15.2
3	0	2	0	SG	0.5	0.08	34.9
3	1	1	0	SG	0.2	0.61	84.5
3	1	2	0	SG	0.2	0.02	0.1
2	0	0	1	SG	0.3	1.21	32.7
2	0	0	2	SG	0.1	0.06	0.4
3	0	0	1	SG	0.3	0.98	39.2
3	0	0	2	SG	0.1	0.09	0.8

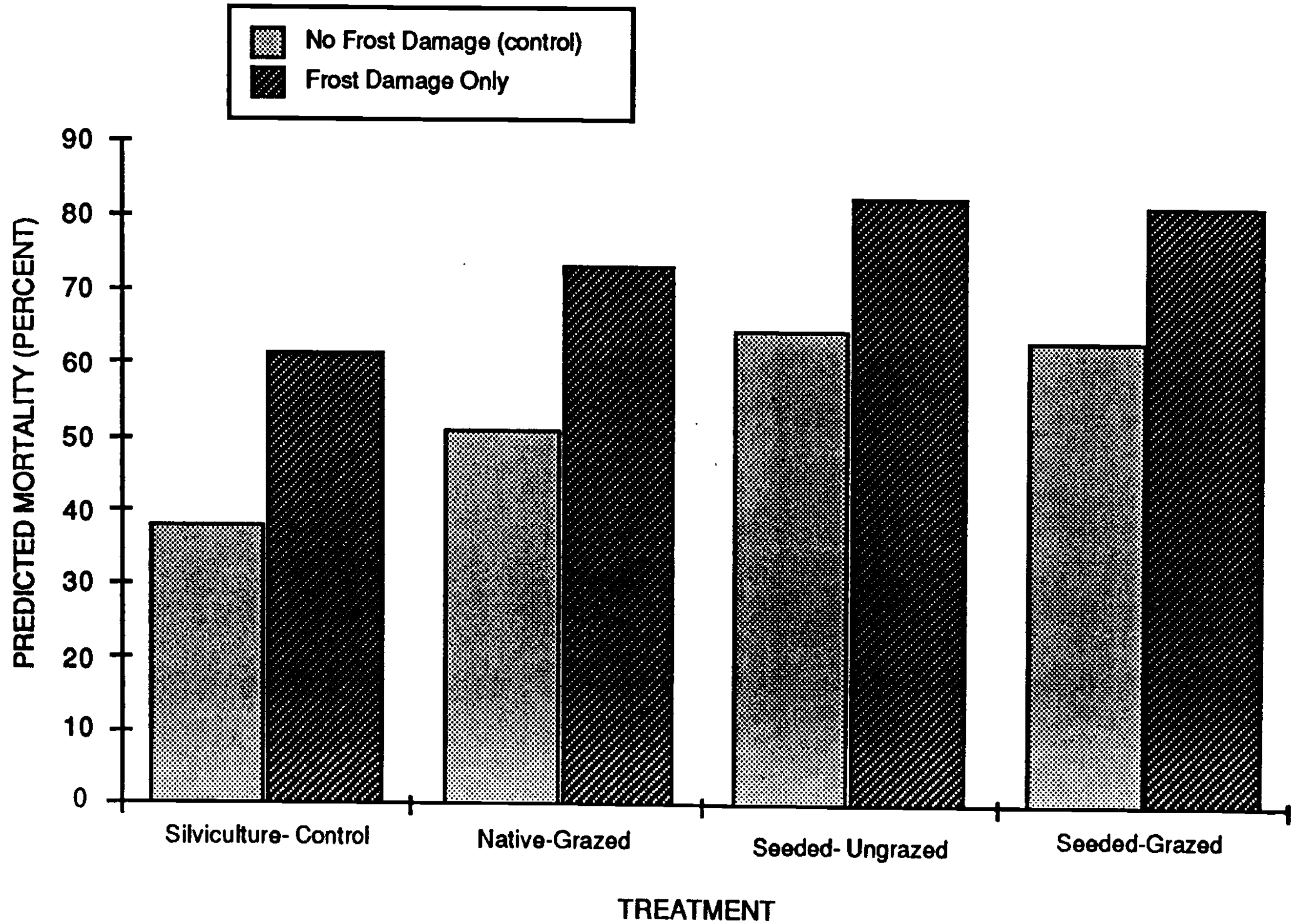

Fig. I.2 Comparison of predicted mortality for Douglas-fir seedlings affected by frost damage with mortality for seedlings not affected by frost damage or any other factor in the binomial response model.

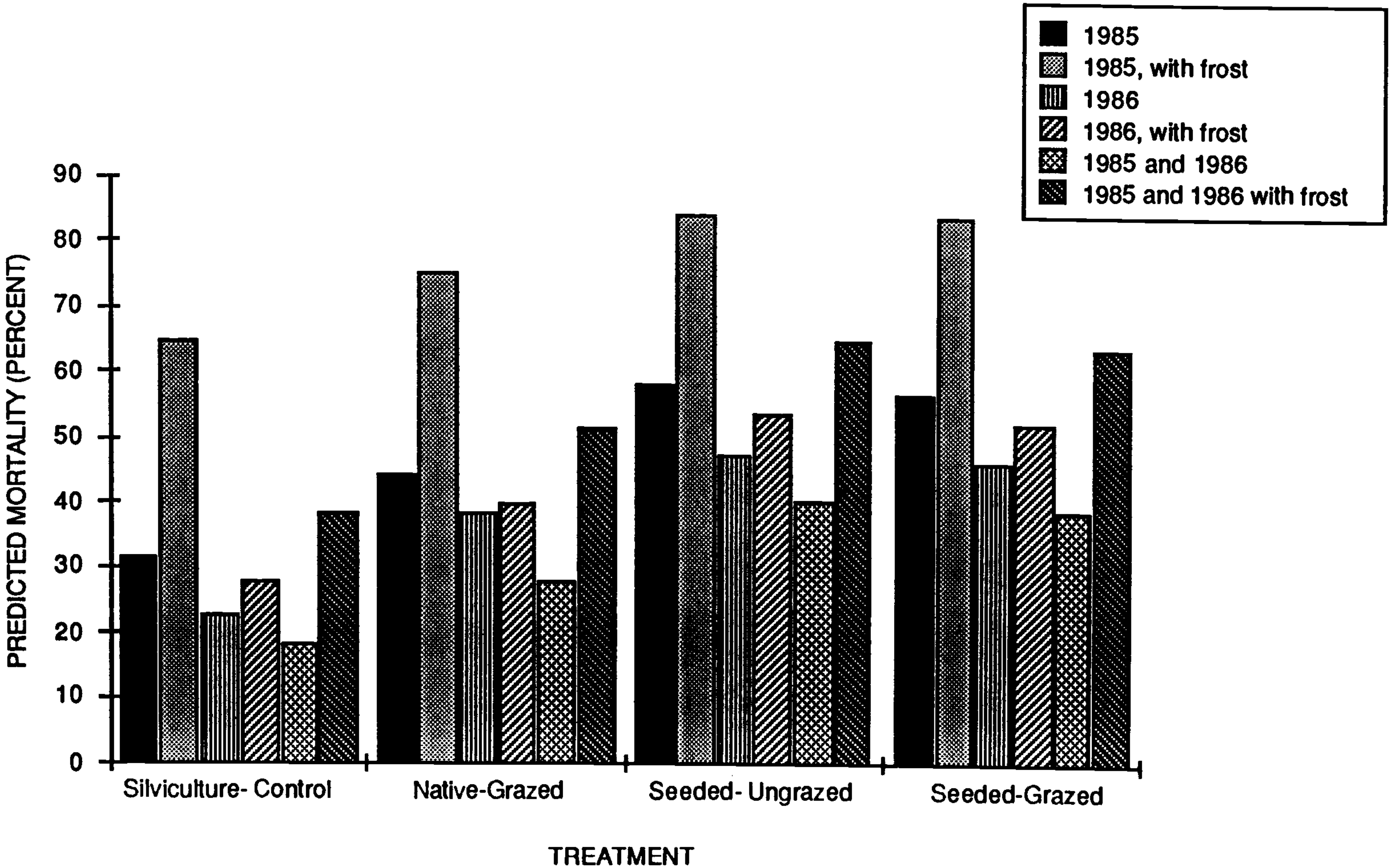

Fig. I.3 Comparison of the predicted mortality for Douglas-fir seedlings when browsed by wildlife in 1985 only, in 1986 only, or when browsed both years. Seedlings frost damaged in addition to being browsed by elk had higher predicted mortalities.

Given the significant results of the test of independence between frost and treatment, it is conceivable that when frost damage occured, predicted mortality would be higher in the seeded treatments relative to the unseeded treatments. However, this relationship also existed for the combinations of variables where no frost damage occured, rather then mortalities in all treatments being similar. When frost damage surveys were conducted in 1985, only those seedlings with outward, physical signs of frost damage (i.e. discoloration and wilting) were recorded as impacted by the frost. It is possible seedlings showing no outward sign of frost damage were internally affected by the frost enough to decrease their potential for survival, yet included in the no frost damage categories. This would prejudice predicted mortalitites for seedlings in the seeded treatments, where incidence of frost was highest.

Predicted mortality with wildlife browsing was increased by frost damage more for trees browsed in 1985 or both years, than for trees browsed in 1986 only (Fig. I.3). More trees were influenced by wildlife browsing in 1986 only, than any other variable in the model (see Tables I.3 and I.5). However, the predicted

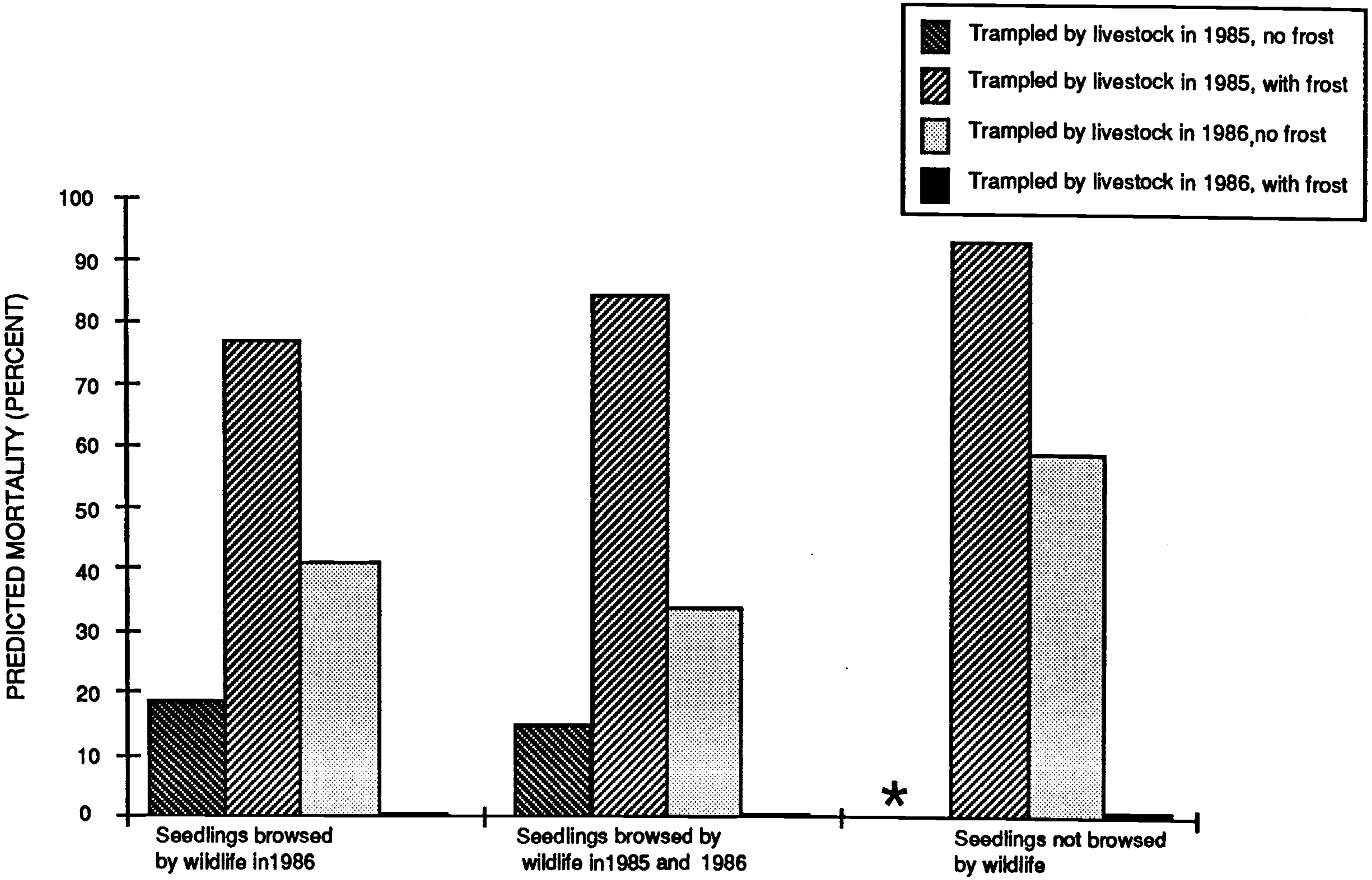

Fig. I.4 Predicted mortality of Douglas-fir seedlings in the seeded-grazed treatment, describing the interaction between livestock trampling and frost damage. Mortalities are for trees affected by a combination of wildlife browsing and livestock trampling. No observations were available for trees trampled by wildlife in 1985, not frost damaged and, not browsed by wildlife (*).

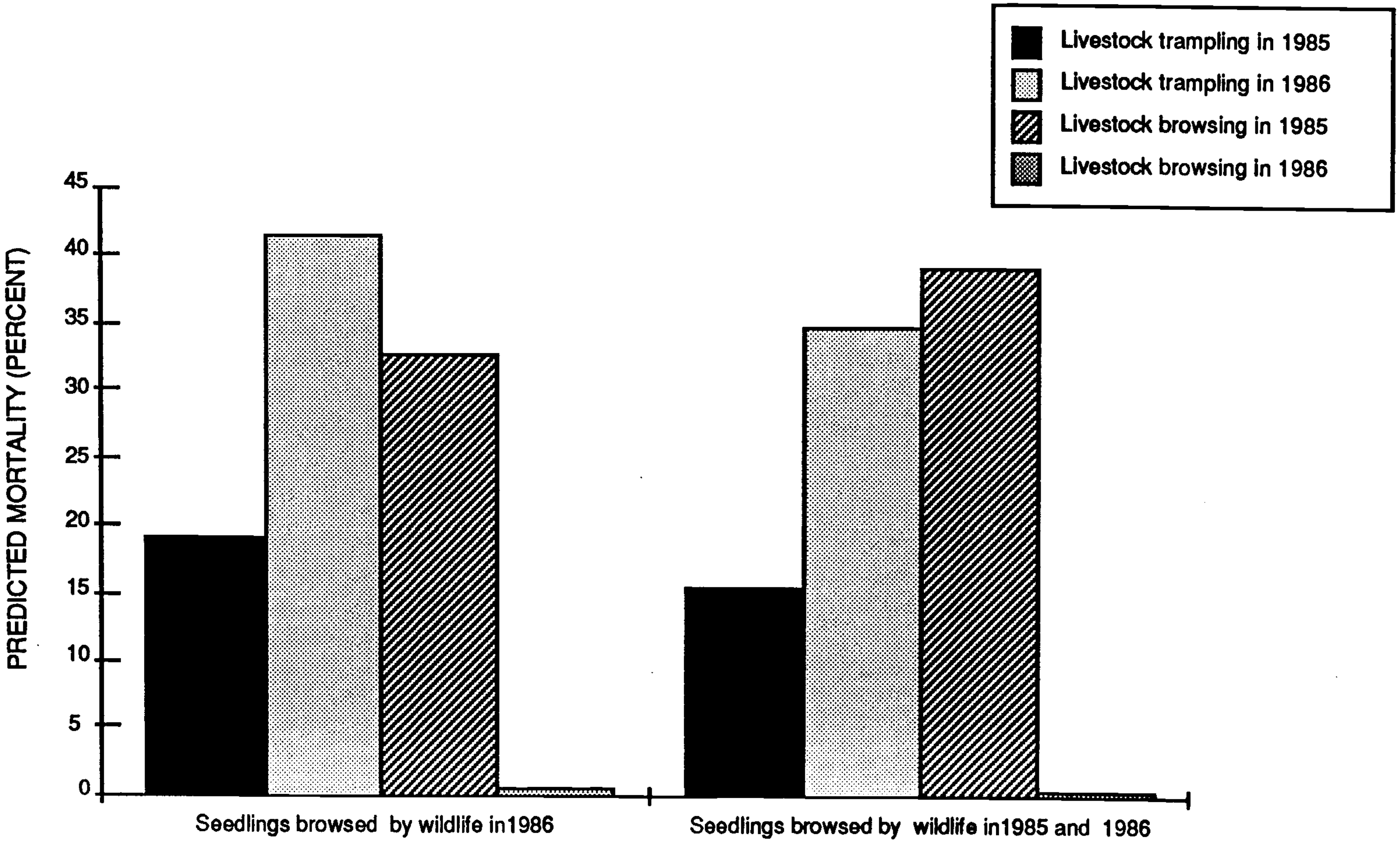

Fig. I.5 Comparison of predicted mortality for Douglas-fir seedlings in the seeded-grazed treatment when trampled or browsed by livestock in 1985 or 1986. Predicted mortalities were derived by the binomial response model using sample trees affected by a livestock impact in combination with wildlife browsing.

mortality of Douglas-fir seedlings browsed by wildlife was lower than the predicted mortality for trees not affected by any of the independent variables (see Fig. I.2). The generally lower mortality for trees browsed by wildlife, even with frost damage (Fig. I.3), indicates when elk heavily browsed seedlings during the second winter and spring, the animals were selecting the healthiest trees, or those which received little or no frost damage.

Figure I.4 describes the interaction between livestock trampling and frost damage on Douglas-fir mortality in 1986, in the seeded-grazed treatment. For livestock trampling in combination with wildlife browsing, the addition of frost dramatically increased the mortality of trees trampled in 1985. In contrast, predicted mortality for trees trampled by cattle in 1986 and frost damaged was negligible. Excluding frost, livestock trampling in 1986 resulted in higher Douglas-fir mortality than livestock trampling in 1985.

Livestock browsing and livestock trampling had differing affects on Douglas-fir mortality. Livestock trampling in 1986 resulted in higher mortality than trampling by cattle in 1985 (Fig. I.5). On the other hand, livestock browsing in 1986 appears to have had little influence on Douglas-fir mortality compared to livestock browsing in 1985.

The variables of frost damage and wildlife browsing had a profound influence on Douglas-fir establishment within the given treatments. In effect, the combinations of independent variables in Table I.5 represent separate populations of Douglas-fir trees within the four treatments.

Attempts to develop a binomial response model for ponderosa pine were unsuccessful due to the relatively low number of pines planted (i.e 227), and the subsequent lack of sufficient information on the independent variables of interest.

Conclusions

Interpretation of Douglas-fir survival and growth response to grazing release treatments in young plantations was hampered by interactions with frost damage and wildlife browsing. Analysis of variance determined Douglas-fir survival did not vary between treatments. However, a chi-square test of independence determined the incidence of frost was highly dependent upon treatment, generally being higher in the seeded treatments.

The binomial response model predicting Douglas-fir mortality can be used to summarize the combined effects of several independent variables on conifer seedling survival. Although analysis of variance resulted in no differences in Douglas-fir survival response to treatments, the predicted mortalities determined by the model suggests differences in survival were present. However, these differences were the result of the factors of frost damage, wildlife browsing and livestock impacts, rather than the treatment applications.

Frost damage was a significant force on Douglas-fir mortality, due to the high percentage of trees affected by frost, and because frost damage generally increased mortality dramatically. Wildlife browsing, though incurred by a relatively large proportion of the seedlings in some treatments, was of somewhat lesser importance because the elk selectively grazed healthier seedlings, resulting in lower mortalities. Relative to each other, livestock browsing and trampling affected seedling mortality differently. Livestock browsing resulted in higher mortality of seedlings the first year of the plantation, having negligible influence on mortality the following year. Mortality due to livestock trampling was higher when trampling occured the second year. Although livestock browsing and trampling could increase seedling mortality, these livestock activities were much less prevalent than wildlife browsing or frost. This suggests that under a controlled plantation grazing program, livestock impacts increasing Douglas-fir mortality can be minimized.

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CHAPTER II

INFLUENCE OF CATTLE GRAZING AND FORAGE SEEDING ON THE WATER RELATIONS OF DOUGLAS-FIR IN SOUTHWEST OREGON

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Influence of Cattle Grazing and Forage Seeding on the Water Relations of Douglas-fir in Southwest Oregon

Abstract

A study was conducted in 1985 and 1986 on two 10ha Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) plantations in southwest Oregon. The goal of the study was to evaluate the potential of livestock grazing and seeding of palatable forages as silvicultural treatments. In 1984, Site 1 was clearcut and burned, and Site 2 was scarified, ripped and burned. Conifers were planted during the spring of 1985, and water relations monitored in silviculture-control, native vegetation-grazed, seeded-ungrazed, and seeded-grazed treatments for two growing seasons. Douglas-fir predawn and midday xylem potentials were not

significantly different between treatments during the first year. In the second year, early season, intense grazing by cattle in the seeded-grazed treatment resulted in seedling xylem potentials similar to xylem potentials for seedlings in the paper mulch treatment. Gravimetric soil moisture content was significantly ($p \leq 0.05$) higher in the silviculture-control treatment on the June sampling date the second year, treatments being similar on all other sampling dates. No differences in understory plant cover were detected between treatments. However, lower standing crop in the seeded-grazed treatment may have reduced transpirational surface and improved water relations of trees on the site. Douglas-fir seedlings in the seeded-ungrazed treatment generally exhibited low xylem potentials, indicating that in this environment, seeding with the exclusion of livestock grazing may result in high water stress for Douglas-fir seedlings.

Introduction

In southwest Oregon, establishment of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) is often difficult due to a combination of rapid site occupancy by herbaceous and woody vegetation and xeric climatic conditions. Vegetation management practices are often prescribed to increase the availability of soil moisture, nutrients and light for growth and survival of the desired tree crop (Newton 1967). In the past, silvicultural prescriptions strongly emphasized the use of herbicides to control vegetation competing with conifer seedlings. However, recent court decisions banning use of herbicides on public forest lands have prompted silviculturists to look for other methods of vegetation control.

Recent investigations point to the potential of using livestock grazing as an alternative vegetation management tool in young conifer plantations (Kosco and Bartolome 1983, Leininger 1983). In general, when animal numbers and season of use are carefully controlled livestock grazing appears to be compatible with conifer establishment. Although plantation grazing studies have demonstrated improved conifer growth with livestock grazing (Krueger 1983, Leininger 1983), examinations to date have compared grazing release treatments to an ungrazed control rather than currently acceptable vegetation control measures. In addition, controversy exists surrounding the suitability of seeding forages into plantations prior to conifer establishment to enhance utilization and control of understory vegetation by livestock (McDonald 1986).

The goal of this research was to assess Douglas-fir seedling response to forage seeding and cattle grazing by intensively measuring tree water relations and understory dynamics. The objectives were: (i) to monitor Douglas-fir predawn and midday xylem potential and soil moisture content throughout the growing season, and (ii) to evaluate understory cover and species composition as influenced by seeding, grazing and conventional site preparation practices.

Study Area

The study area is located eight miles northeast of Butte Falls, Oregon on land administered by the Medford District of the Bureau of Land Management. This region is the southern-most portion of the Western Cascade Physiographic and Geologic province, which developed from volcanic flows and pyroclastics (Franklin and Dyrness 1973). Elevation is 987m and characterized by a mediterranean-type climate with a mean annual precipitation of 88.9cm occuring as rain in the fall and spring, and snow and rain in the winter (deMoulin et al 1975). Average seasonal temperatures range from -1°C in January to 18°C in July. Summers are typically hot and dry.

Douglas-fir is the most abundant conifer in the mixed-conifer vegetation zone typical of mid-elevations in the southwestern flank of the Cascades (Franklin and Dyrness 1973). Sugar pine (*Pinus lambertiana*), ponderosa pine (P. *ponderosa*) and Incense cedar (*Calocedrus decurrens*) occur as scattered individuals, and white fir (*Abies concolor*) is present as seedlings and saplings. Hardwoods include vine maple (*Acer macrophyllum*), pacific madrone (*Arbutus menziesii*), and chinquapin (*Castanopsis chrysophylla*). Primary shrub and herbaceous components within mature stands are California hazel (*Corylus cornuta* var. *californica*), creek dogwood (*Cornus nutallii*), oregongrape (*Berberis nervosa*), western yew (*Taxus brevifolia*), trailing blackberry (Rubus ursinus), oceanspray (Holodiscus discolor), and deerfoot vanillaleaf (Achlys triphylla). Blue wildrye (Elymus glaucus) is by far the most abundant grass in stand openings, with lesser amounts of foxtail fescue (Vulpia megulara) and Kentucky bluegrass (Poa pratensis).

Soils in the study area are represented by the Freezener and Geppert soil series, with the shallower Geppert soils occuring on ridge tops, and the deeper Freezener occupying side slopes (deMoulin et al 1975). Soils in the Freezener series (classified as mixed, mesic Ultic Haploxeralfs) have deep (102-152cm), well-drained profiles formed from basic igneous rock. These soils have dark reddish brown gravelly loam A horizons, and reddish brown silty clay Bt horizons. The Geppert series (classified as loamy-skeletal, mixed, mesic Dystric Xerochrepts) consists of moderately deep (50-100cm), well-drained soils formed from volcanic breccia or andesite. They have dark reddish brown cobbly clay loam A horizons, and dark reddish brown cobbly clay loam B horizons. Both soils have a high frost-heave potential.

Treatments as described in the methodology section were applied on two adjacent sites. Slopes ranged from

5 to 25 percent on both sites. Site 1 which has south to southwest, and west to northwest exposures, originally supported a second growth mixed-conifer stand. Douglas-fir was the dominant conifer in this stand and the associated overstory and understory vegetation was similar to the mixed-conifer vegetation previously described. Tractor logging produced a 9.7ha clearcut in June, 1984. Site preparation was accomplished by broadcast burning of slash in early October, 1984. Site 2 was occupied by a 20-year-old ponderosa pine plantation with southeast, west and northwest aspects. The understory vegetation was dominated by perennial and exotic annual grasses and trailing blackberry. The plantation was in poor condition due to the use of pine stock not suited to this environment, and severe soil compaction caused by winter logging in the past. In August, 1984, a 10.5ha unit was scarified and piled, followed by ripping of compacted soil layers. Slash piles were burned in the fall. In the winter of 1985, both sites were planted to a 1.8m x 1.8m spacing (2200-2500 trees/ha) of 2-0 bare root Douglas-fir and ponderosa pine seedlings at a ratio of 5 Douglas-fir to 1 ponderosa pine.

Methods and Materials

Treatments

Treatments were applied to both Site 1 and Site 2 in a randomized block design with two blocks per site and one replication of each treatment in each block. Four treatments were applied to both Site 1 and Site 2:

(1) Silviculture-control (SC): Currently available silvicultural methods were used to control vegetation competition. Application of this treatment was the responsibility of silviculturists in the Medford District, Bureau of Land Management. A treatment was considered unnecessary the first year (1985), with a paper mulch application utilized in early spring, 1986. No grazing occurred in this treatment.

(2) Native-grazed (NG): Livestock grazing alone was used to control competition with successional vegetation naturally invading the site. The Native-grazed treatments on Site 1 were not grazed in 1985 or 1986 due to lack of palatable forage for cattle, basically serving as a control treatment.

(3) Seeded-ungrazed (SU): Grass-legume mix seeded and no grazing. This was viewed as the high competition treatment.

(4) Seeded-grazed (SG): Seeded with the same grass-legume mix, but including livestock grazing in 1985 and 1986.

SU and SG were seeded in the fall of 1984, soon after prescribed burning of Site 1. Justification for these treatments was based on the assumption that transformation of understory vegetation to highly palatable forage would curtail enchroachment of woody vegetation and focus grazing on forage, thereby increasing utilization and ultimately control of competing vegetation. The criteria for selection of the desired grass-legume mix were high palatability and/or the ability to establish rapidly on similar sites. The seeding mixture was applied at a ratio of 14.6 kg/ha and included perennial ryegrass (<u>Lolium perenne</u>, `Linn' variety at 1.7 kg/ha), orchardgrass (<u>Dactylis glomerata</u>, `Potomac' variety at 5.6 kg/ha), white clover (<u>Trifolium repens</u>, `New Zealand' variety at 1.7 kg/ha), and subterranean clover (<u>Trifolium subterraneum</u>, `Mt. Barker' variety at 5.6 kg/ha). Inadequate establishment due to frost heaving and lack of winter and spring precipitation called for a second seeding in March, 1985, using orchardgrass alone at a rate of 14.6 kg/ha.

The effectiveness of a release treatment is dependent upon appropriate timing of the procedure, i.e. before soil moisture is depleted by competing vegetation (Newton 1967). It then follows that the success of the grazing release treatments should be dependent upon proper timing of grazing. Therefore, grazing treatments were applied to encourage the highest utilization and greatest reduction in vigor of available forage. Grazing management criteria were: (1) Early grazing to decrease soil moisture depletion and graze when grass phenology was vegetative and palatable. Defoliation at this time coincides with the period of active growth and depletion of carbohydrate stores, resulting in reduction of vigor (Moser 1977). (2) Graze at a high intensity (approximately .2 ha/AUM), and (3) graze significant levels of regrowth.

To accomplish vegetation management with cattle, put-and-take grazing (Wheeler et al 1973) was utilized, where stocking rate was varied as frequently as the availability of the forage required. During each grazing period, removal of animals from pastures was based on a reduction in available forage to approximately 5cm stubble height of grasses, and increasing levels of livestock trampling as judged by visual observation. In 1985, both single cows and cow-calf pairs were used, while only pairs grazed in 1986. To facilitate proper livestock control, a 1.2m high barbed-wire fence was established around the perimeter of each site. Fencing of individual treatments was accomplished with portable electric fencing during grazing periods. A description of pastures and animal use is provided in Table II.1.

Water Relations

Predawn and midday Douglas-fir xylem potential were monitored throughout the growing season with the use of a pressure chamber (Waring and Cleary 1967). Midday samples were collected between 12pm and 2pm in the afternoon, and predawn samples between 1am and 2am the following morning. Within each treatment replication, twig samples were collected from six randomly selected seedlings for each collection period. Prior to cutting, twigs were covered with a small plastic bag to reduce evapotranspiration, excised

Table II.1. Description of pastures, cattle numbers, and grazing use on Site 1 and Site 2, 1985 and 1986.

Site	Treatment	Year	Area Grazed (ha)	No. of Grazing Periods	Animal Nos. per Grazing Period	Total Animal Days of Grazing
1	Seeded-	1985	2.8	2	8, 9	44
	Grazed	1986	2.8	2	29, 9	156
2	Native-	1985	5.3	1	4	20
	Grazed	1986	5.3	1	14	80
	Seeded-	1985	5.3	1	8	20
	Grazed	1986	5.3	2	10, 6	95

and wrapped in the bag, placed on ice under conditions of darkness (Turner 1981), and taken back to a laboratory. In 1985, water potential was measured prior to grazing treatments, and repeated at three week intervals through September. Severe frost damage of seedlings in 1985 limited tree numbers for sampling in 1986 (Alejandro-Castro 1988). In the second year, Douglas-fir xylem potential was monitored beginning two weeks after grazing had begun, and repeated at four week intervals ending in September. In 1986, adequate tree numbers for random sampling were available in only one block at each site.

Percent soil moisture content was obtained by the gravimetric method (Gardiner 1965). Soil samples were collected the morning prior to midday xylem potential measurements. For each sampling period, three sampling points per replication were randomly selected within 2 feet of seedlings already selected and marked for water potential analysis. Soil samples collected in the SC treatment in 1986 were taken outside the perimeter of the paper mulch. Soil was collected at 0-10, 10-20, and 20-30cm depths. Fig. II.1 represents daily precipitation (mm) recorded at the Butte Falls Ranger

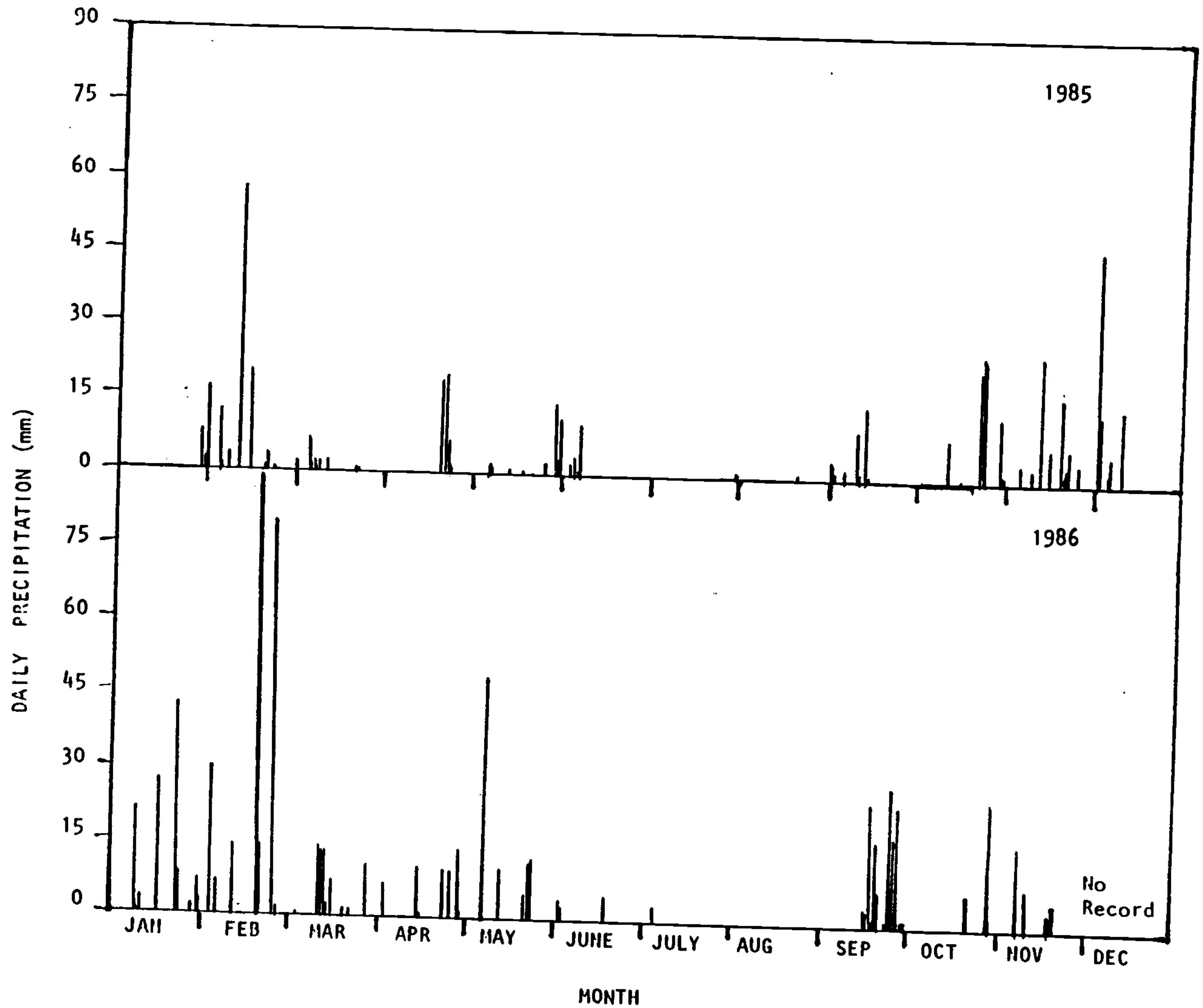

Fig. II.1. Daily precipitation (mm) recorded at the Butte Falls Ranger Station, Rogue River National Forest, Butte Falls, Oregon, from January, 1985 to November, 1986.

Station, Butte Falls, Oregon, located 7 miles southwest of the study site.

Understory Measurements

Treatment effects on understory plant cover were monitored both years beginning in July, after grazing had ended and when perennial grasses and forbs had a visible inflorescence. Seven 30.5m permanent line transects were established within each treatment replication, and percent shrub cover estimated using the line intercept method (Canfield 1941). Herbaceous cover was estimated at 3.05m intervals along these same transects using a point frame (Levy 1933, Levy and Madden 1933). Pins were held perpendicular to the ground surface within an 83.8cm by 78.5cm metal frame. The 86.4cm length pins were placed 5.5cm apart on the frame. Only first plant hits per point were recorded.

Standing crop estimates were derived from plots clipped at the end of the grazing season, in early July, 1986. Three plot transects were randomly selected in each replication and vegetation clipped at ground level from a total of 30, .5-square meter plots. Clipped samples were bagged, oven dried at 50°C for 48 hours, and weighed.

Treatment differences were analyzed using analysis of variance (Snedecor and Cochran 1980). A probability value of $p<0.05$ was used throughout the analysis to test significance of F values. Limitation of water potential analysis to one block on each site in 1986 resulted in no block replication, and therefore a formal test comparing sites could not be made. Comparisons of treatment means were tested using the Newman-Keuls method, where means were significantly different at $p<0.05$ (Snedecor and Cochran 1980).

Results

Water Relations

In 1985, differences between treatments did not exist for predawn or midday xylem potential of Douglas-fir seedlings (Fig. II.3 and II.4). Significant date by site interactions were present in 1985 for both predawn and midday analyses (Fig. II.2). Douglas-fir seedlings on Site 1 experienced less negative xylem potentials than trees on Site 2. Xylem water potential was more negative on Site 2, and

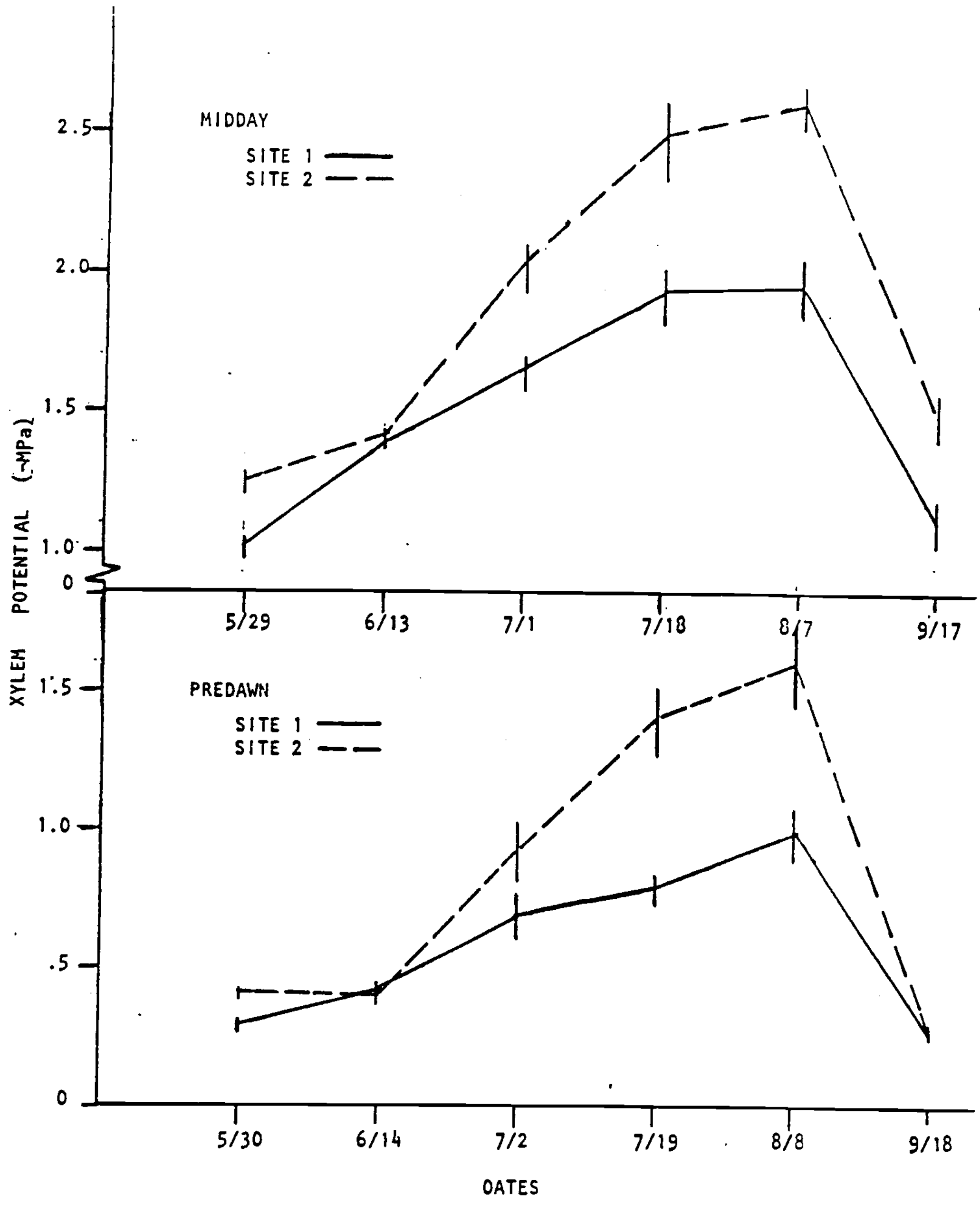

Fig. II.2. Comparison of predawn and midday xylem potentials for Site 1 and Site 2 in 1985. A significant ($p \leq 0.05$) date by site interaction was present. Vertical lines represent standard errors.

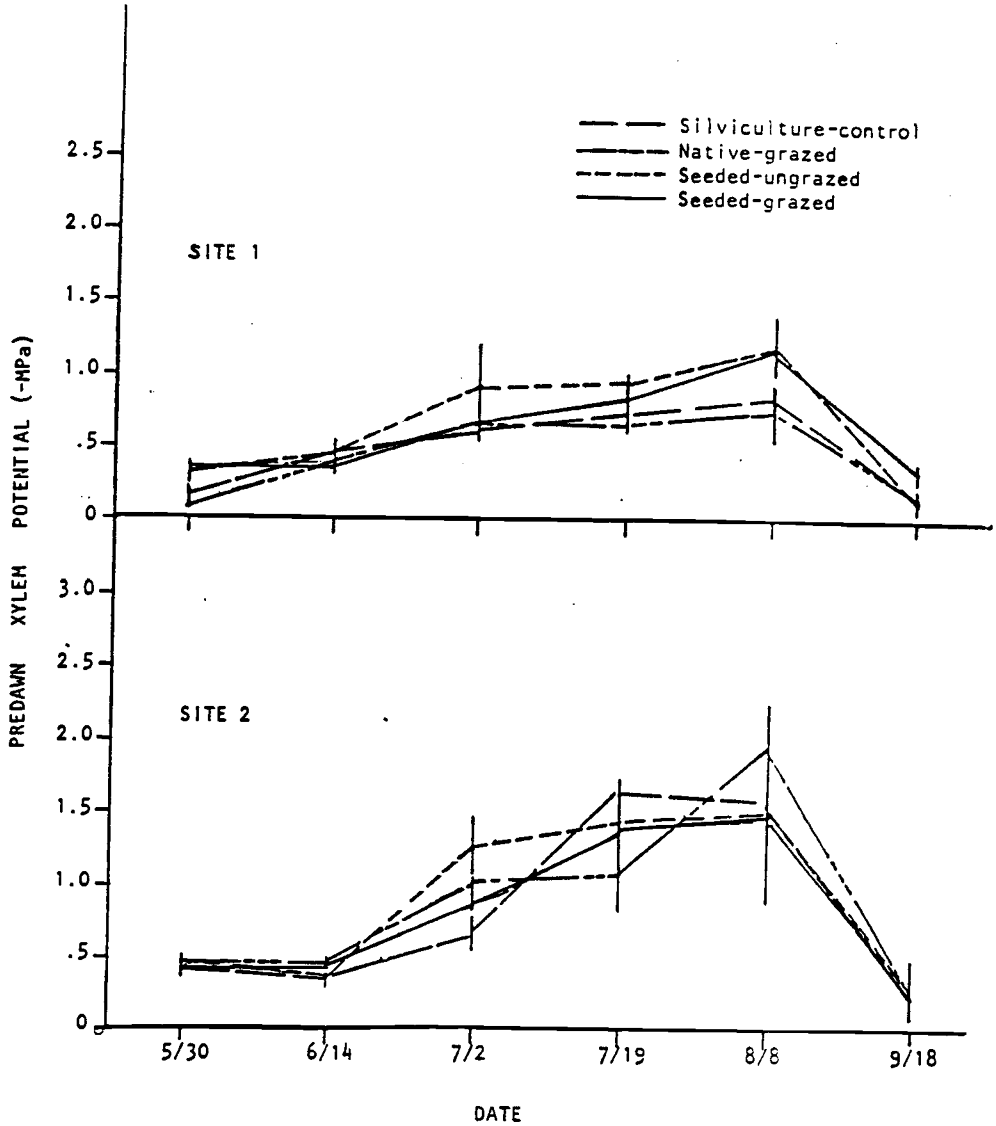

Fig. II.3. Predawn xylem potential for Douglas-fir seedlings, by treatment, on Site 1 and Site 2, in 1985. Treatment means were not significantly different ($p \leq 0.05$). Vertical bars are standard errors of the mean. The Native-grazed treatment on Site 1 received no grazing treatments.

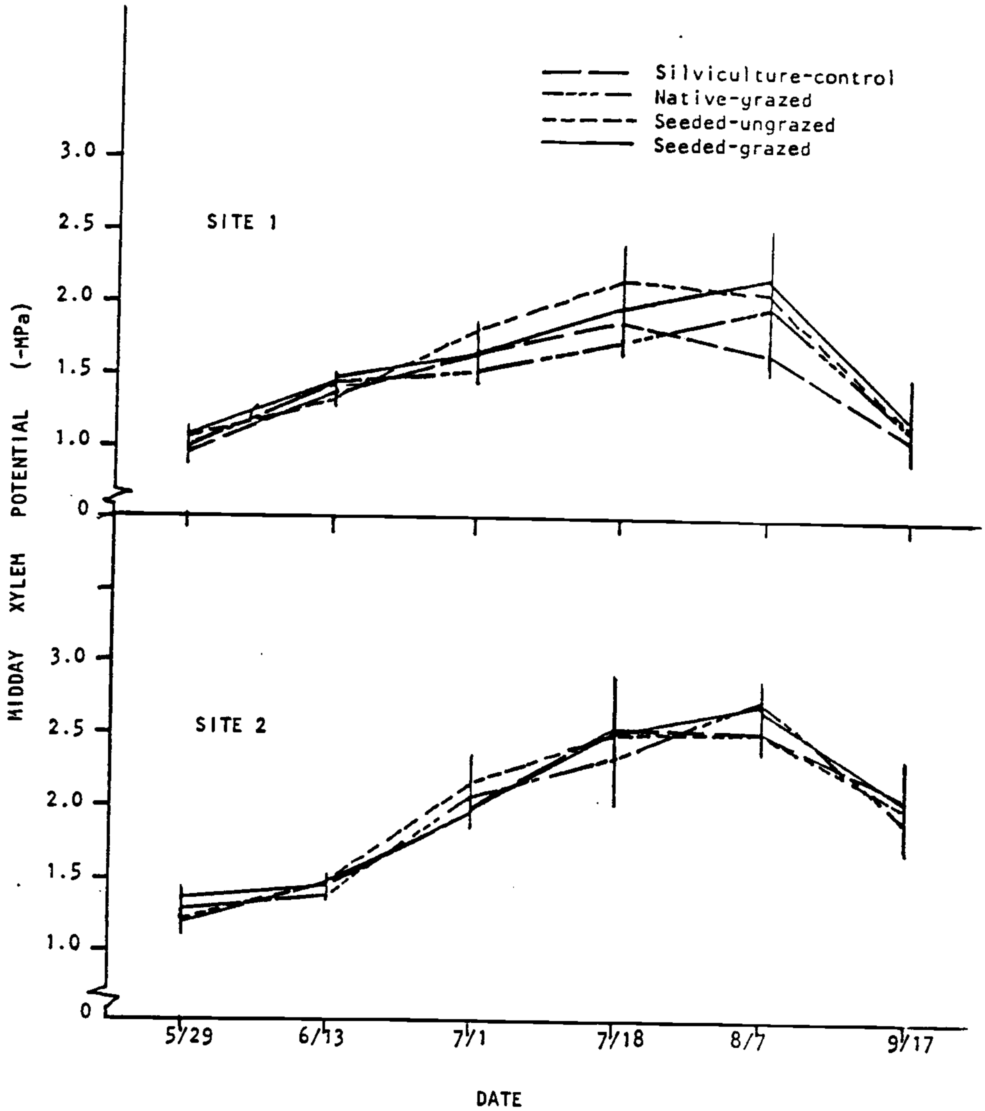

Fig. II.4. Midday xylem potential (-MPa) for Douglas-fir seedlings in 1985, on Site 1 and Site 2. Treatment means were not significantly different ($p \leq 0.05$). Vertical bars are standard errors of the mean. No grazing treatments were applied to the Native-grazed treatment on Site 1.

decreased more rapidly as the summer drought progressed as compared to Site 1. Figs. II.3 and II.4 describe Douglas-fir predawn and midday water potential response to treatments in 1985.

In 1986, a significant date by treatment interaction was detected on both sites for the predawn xylem potential measurements. Multiple comparison of treatment means on each sampling date are summarized in Table II.2. Analysis of two-way interaction means revealed the following relationships for the predawn xylem potential analysis:

1. As the summer drought increased, xylem potentials decreased in all treatments (Fig. II.5).
2. On both sites, the trend was for trees growing in the SG (Seeded-grazed) and SC (Silviculture-control) treatments to experience less drought than seedlings in the NG (Native-grazed) and SU (Seeded-ungrazed) treatments. This relationship took place on Site 1 during the June and August sampling date (Fig. II.5), and on Site 2 during the August sampling date.
3. Predawn xylem potential for Douglas-fir seedlings growing in the SC and SG treatments were not

Table II.2. Multiple comparison of Douglas-fir xylem potential (-MPa) treatment means at each sampling date in 1986. Means followed by similar letters are not significantly different on that date ($p \leq 0.05$).

Predawn Xylem Potential

		Date			
Site 1	Treatment	6-19	7-18	8-14	9-12
	SC*	0.45a	0.53a	1.02a	1.45b
	NG	1.23b	0.63a	1.16a	2.13c
	SU	1.08b	1.10b	1.49b	1.59c
	SG	0.44a	0.61a	1.16b	1.07a
Site 2	SC	1.35a	0.96a	1.24a	1.73a
	NG	1.26a	1.68ab	1.97b	2.21b
	SU	1.25a	1.38b	2.22b	2.20b
	SG	0.68b	1.35ab	1.43a	1.92ab

Midday Xylem Potential

		Date			
Site 1	Treatment	6-18	7-17	8-13	9-11
	SC	2.17c	1.69ab	1.59a	1.83a
	NG	1.46a	1.93b	2.68b	2.39b
	SU	1.89bc	2.05b	2.20c	2.33b
	SG	1.75ab	1.53a	1.87a	2.00a
Site 2	SC	1.58a	2.17a	2.38a	2.72a
	NG	2.30b	2.44b	2.76b	2.81a
	SU	2.24b	2.71c	2.90c	2.86a
	SG	1.80a	2.27a	2.61ab	2.60a

*SC = Silviculture-control, NG = Native-grazed, SU = Seeded-ungrazed, and SG = Seeded-grazed treatments. Grazing treatments were not applied to the Native-grazed treatment on Site 1 in 1985 or 1986.

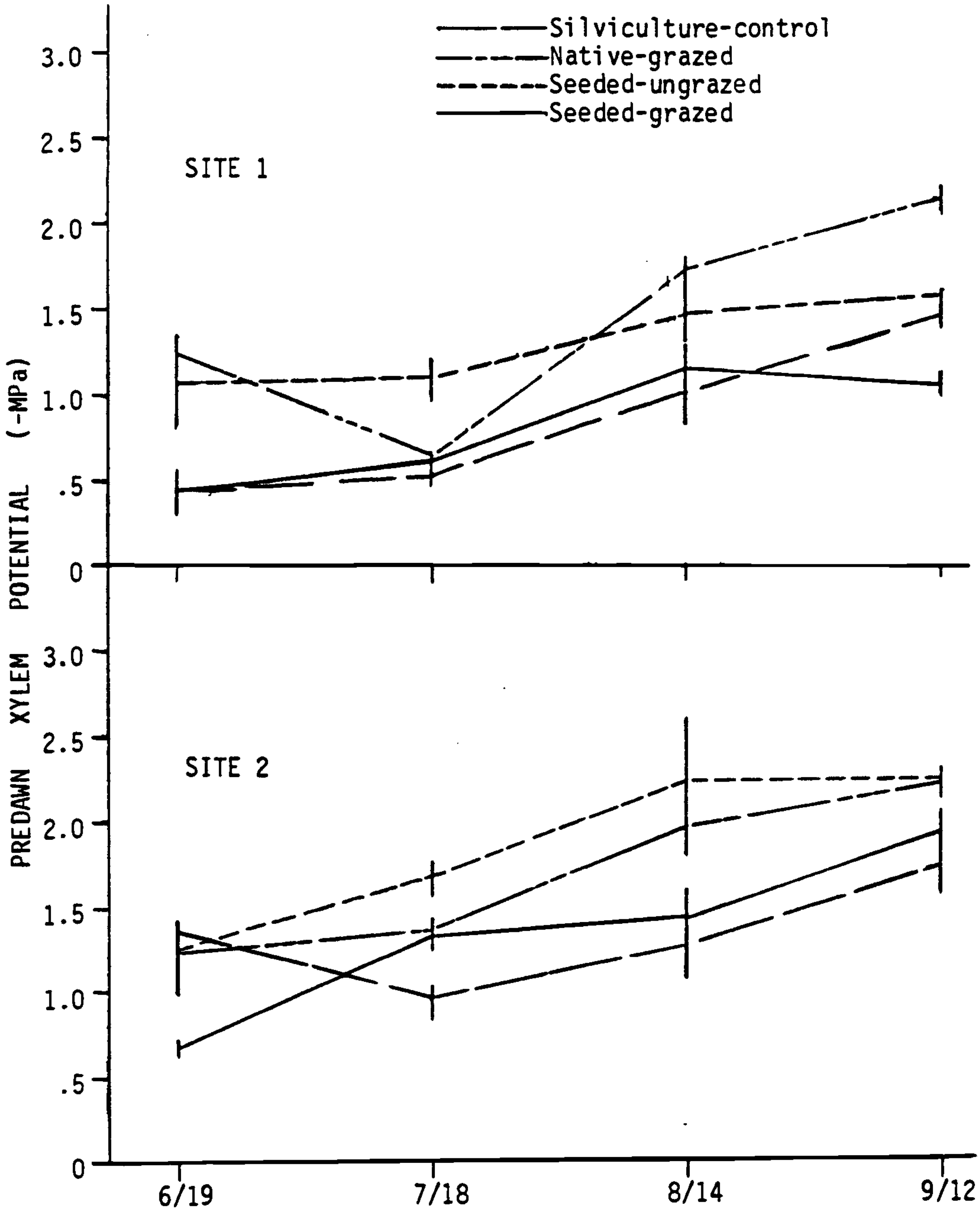

Fig. II.5. Douglas-fir predawn xylem potential response to treatments on Site 1 and Site 2 in 1986. A significant ($p \leq 0.05$) treatment by date interaction was detected on both sites. Vertical bars are standard errors. No grazing treatments were applied to the Native-grazed treatment on Site 1.

different on most dates except for the September date on Site 1, and the June readings on Site 2 when trees in the SG treatment had significantly less negative xylem potentials.

4. Xylem potentials for seedlings in the SU and NG treatments on Site 2 were similar on all dates. On Site 1, xylem potentials for seedlings in these treatments differed on the July and September sampling dates.
5. Predawn xylem potentials of seedlings in the SG and SC treatments on Site 1 stayed below 1.5 MPa throughout 1986 (Fig. II.5).
6. On Site 2, trees in NG and SU conditions experienced high moisture stress (>1.5MPa) approximately one month earlier than seedlings in the SC and SG treatments (Fig. II.5).

Analysis of variance for Site 1 midday xylem potentials also resulted in a significant date by treatment interaction (Fig. II.6). Analysis of midday xylem potential revealed the same similarity as predawn values between the SC and SG treatments and the NG and SU treatments, particularly on the August and September sampling dates. In September, xylem potentials for NG and SU did not differ, but in August, xylem potentials

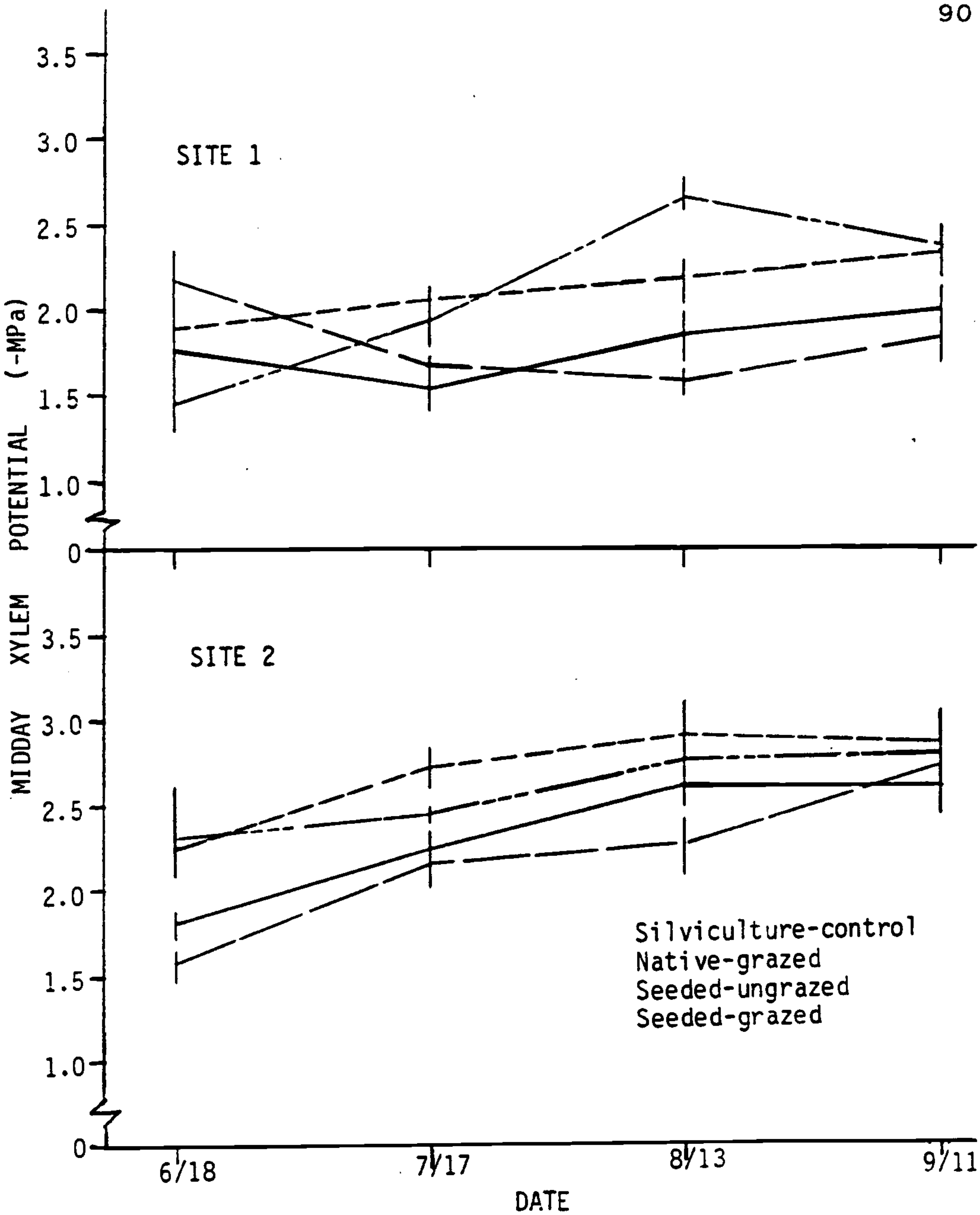

Fig. II.6. Douglas-fir midday xylem potential response to treatments in 1986, on Site 1 and Site 2. The treatment means on Site 2 and the treatment by date interaction on Site 1 were significantly different ($p \leq 0.05$). Vertical bars are standard errors. No grazing treatments were applied to the Native-grazed treatment on Site 1.

were higher for trees in the SU treatment (Table II.2). Treatment differences in June were not consistent with the general trend. In contrast, seedlings growing in the NG treatment experienced less drought than seedlings growing in the SC and SU treatments.

Site 2 midday water potential analysis had no date by treatment interaction, although treatment differences were significant (Fig. II.6). A multiple comparison of treatment means averaged over the four dates found less negative xylem potential readings for trees in the SC and SG treatments than in the NG and SU treatments. As the summer dry period continued, water stress increased in all treatments into August, followed by little change in stress levels in September, except for the SC treatment which continued to increase.

<u>Soil Moisture</u>

In 1985, levels of soil moisture did not differ between the four treatments and the two sites. A significant interaction was present between date and depth of sampling (Fig. II.7). From June through August, the surface layer (0-10cm) of soil had less

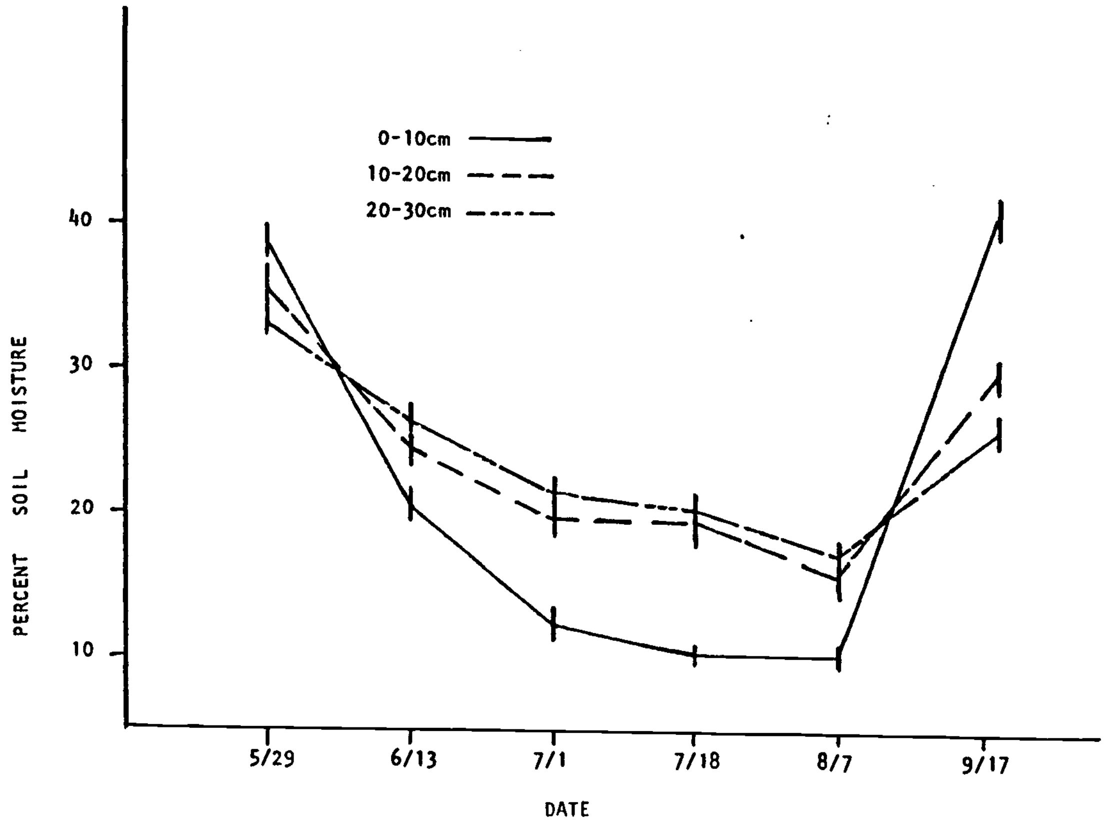

Fig. II.7. Trend in percent soil moisture content at each soil depth in 1985. Depth means on a given date are averaged over treatments and sites. Vertical bars represent standard errors. The depth by date interaction was significant ($p \leq 0.05$).

moisture than the deeper depths, corressponding with development of the summer drought. The higher soil moisture content at the surface in May and September was due to periods of rainfall preceding these sample collection dates (Fig. II.1).

In 1986, Site 1 had higher soil moisture content than Site 2 during the June and July sampling periods (Fig. II.8). Soil moisture content in the August sampling period was not different between the two sites. Comparison of soil moisture among treatments revealed a similar response on both sites. Evaluation of a significant treatment by date interaction (Fig. II.9) determined SC had significantly more soil moisture present in June than the other treatments on both sites. Treatment means on the other dates did not differ.

Plant Cover

Total shrub cover did not vary between treatments or years (Table II.3). Total herbaceous cover was not significantly different between treatments in 1985 or 1986 (Table II.3). A higher percentage of herbaceous plants was present the second year of the plantation on both sites. Although treatments did not differ in

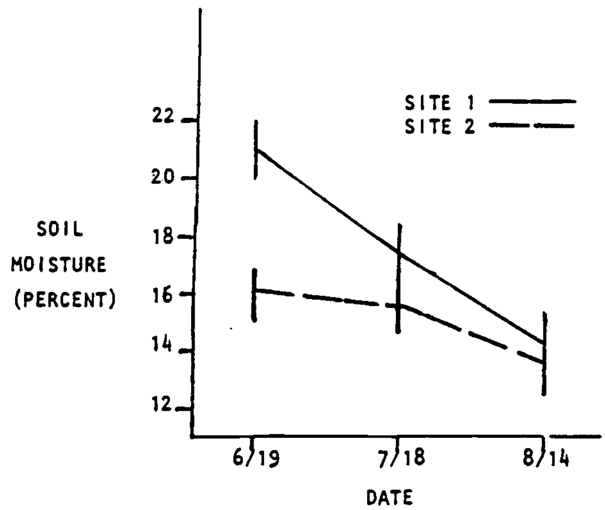

Fig. II.8. Graph of the site by date interaction ($p \leq 0.05$) for percent soil moisture content in 1986.

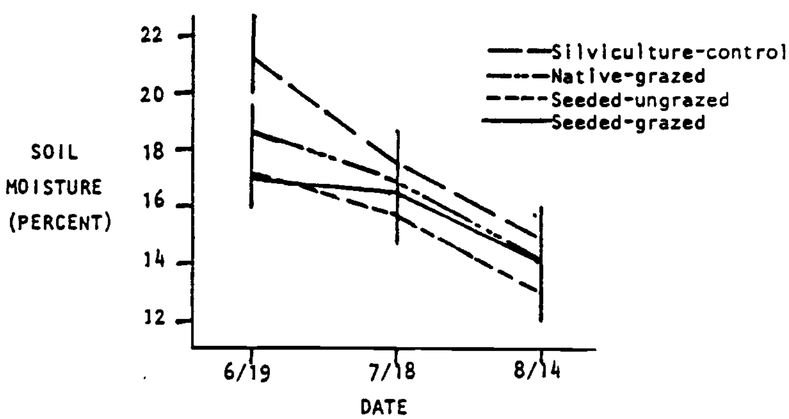

Fig. II.9. Soil moisture content (percent) for treatments averaged over sites in 1986. The date by treatment interaction was significant ($p \leq 0.05$). Vertical bars are standard errors.

Table II.3. Mean percent cover (and standard error) of plant groups for each treatment on Site 1 and Site 2 in 1985 and 1986.

Plant Group	Silviculture-Control 1985	Silviculture-Control 1986	Native-Grazed 1985	Native-Grazed 1986	Seeded-Ungrazed 1985	Seeded-Ungrazed 1986	Seeded-Grazed 1985	Seeded-Grazed 1986
Total Herbaceous[1,2]								
Site 1	3.9	9.1	3.0	11.6	8.4	12.6	6.7	10.0
	(1.14)	(1.00)	(0.71)	(1.07)	(1.22)	(0.28)	(0.86)	(0.57)
Site 2	5.8	14.2	10.8	17.2	13.2	19.7	14.0	14.6
	(1.50)	(1.72)	(0.78)	(1.86)	(6.78)	(0.28)	(5.29)	(2.64)
Dactylis Glomerata[2]								
Site 1	—	—	—	—	5.2	6.9	4.6	5.7
					(0.50)	(1.22)	(1.07)	(1.42)
Site 2	—	—	—	—	2.4	3.6	3.7	4.3
					(1.43)	(1.00)	(0.14)	(0.28)
Lolium perenne								
Site 1	—	—	—	—	1.2	2.6	1.6	1.9
					(0.14)	(1.0)	(0.0)	(0.22)
Site 2	—	—	—	—	1.1	0.5	2.2	0.9
					(0.64)	(0.21)	(1.78)	(0.28)
Perennial Grass[3]								
Site 1	0.3	0.5	0.1	0.1	0.2	0.1	0	0
	(0.29)	(0.36)	(0.0)	(0.0)	(0.07)	(0.07)		
Site 2	0.9	1.2	0.7	1.3	0.9	1.2	0.5	0.9
	(0.71)	(0.92)	(0.01)	(0.01)	(0.14)	(0.07)	(0.07)	(0.28)
Annual Grass[3]								
Site 1	0.2	1.5	0	0	0	0.2	0	0.1
	(0.22)	(1.50)				(0.22)		(0.07)
Site 2	1.1	3.2	1.4	3.8	2.5	5.7	1.6	2.9
	(0.07)	(0.36)	(0.01)	(0.64)	(1.22)	(0.51)	(1.22)	(1.01)
Perennial Forb[4]								
Site 1	0.6	0.2	0.4	0.6	0.5	0.2	0.1	0.1
	(0.0)	(0.08)	(0.43)	(0.64)	(0.50)	(0.22)	(0.07)	(0.07)
Site 2	1.0	0.7	1.8	0.2	0.9	0.9	0.1	0.2
	(0.14)	(0.43)	(0.50)	(0.15)	(0.86)	(0.57)	(0.28)	(0.15)
Annual Forb[1]								
Site 1	0.5	0.9	0.6	0.6	1.1	0.2	0	0
	(0.21)	(0.22)	(0.0)	(0.15)	(0.08)	(0.15)		
Site 2	0.8	0.6	1.7	0.3	1.2	0.4	1.9	0.3
	(0.51)	(0.36)	(0.13)	(0.15)	(1.07)	(0.29)	(1.29)	(0.15)
Biennial Forb[2,5]								
Site 1	2.3	6.1	1.9	10.1	0.1	2.0	0.4	2.2
	(0.86)	(1.07)	(0.29)	(1.86)	(0.15)	(0.72)	(0.29)	(0.64)
Site 2	2.1	8.4	5.2	11.7	4.4	7.5	3.2	5.4
	(0.36)	(1.29)	(0.07)	(2.50)	(1.50)	(0.22)	(0.72)	(1.36)
Total Shrub								
Site 1	4.4	3.0	5.0	5.1	2.6	3.4	2.5	1.86
	(0.04)	(0.69)	(1.86)	(2.18)	(0.13)	(1.26)	(0.20)	(0.47)
Site 2	0.8	0.7	0.8	0.5	1.0	0.9	0.8	0.5
	(0.64)	(0.25)	(0.77)	(0.20)	(0.17)	(0.52)	(0.31)	(0.21)

The following means were significantly different ($p \leq 0.05$): 1-site means, 2-years, 3-year x site interaction means, 4-year x site x treatment interaction means, 5-year x treatment interaction means. The Native-grazed treatment on Site 1 received to grazing treatments in 1985 or 1986.

their total herbaceous cover, considerable variation existed between sites and treatments in the dominant herbaceous component groups and in species composition (Table II.3).

When comparing sites, total herbaceous cover was higher on Site 2 than Site 1 both years (Table II.3). Of the seeded species, orchardgrass occupied more area on Site 1 than on Site 2. Species composition of seeded treatments on Site 1 was dominated by the seeded grasses. Each year, orchardgrass and perennial ryegrass comprised at least 75 percent of the total herbaceous cover in the seeded treatments on Site 1, and only 20 to 41 percent on Site 2. Total cover of either seeded grass species was not significantly different between SG and SU treatments.

Total cover of native perennial graminoids was greater on Site 2 and increased in 1986, whereas Site 1 levels remained nearly constant between the two years (Table II.3). Important species in this group were blue wildrye, timber oatgrass (_Danthonia intermedia_), Canada bluegrass (_Poa compressa_), Kentucky bluegrass, and Lemmons needlegrass (_Stipa lemmonii_) on Site 2, and blue wildrye and manyrib sedge (_Carex multicostata_) on Site 1. Analysis of variance of total annual grass cover resulted in a similar significant year by site interaction. Site 2 carried a higher percentage of annual grass cover and increased more dramatically in 1986 as compared to Site 1. Soft chess (*Bromus mollis*), cheatgrass (B. *tectorum*) and foxtail fescue (*Vulpia megulara*) where the most prevalent annual grasses.

Biennial forb cover was significantly greater on Site 2 than on Site 1 in 1985 and 1986 (Table II.3). Flannel mullein (*Verbascum thapsus*) was more common on Site 2, whereas bull thistle (*Cirsium arvense* var. *horridum*) and woodland tarweed (*Madia madiodes*) occured equally on both sites. In the second year, these forbs had increases of a greater magnitude in the SC and NG treatments as compared to the seeded treatments. Annual forbs such as sheep sorrel (*Rumex acetosella*) and variedleaf collomia (*Collomia heterophylla*) were more prevalent the first year of the plantation, their cover decreasing significantly in 1986. Differences in perennial forb cover are complicated by a significant three way interaction between year, site and treatments. The NG treatment had a higher percentage of perennial forbs, followed by SC, SU, and SG. Several of the treatments experienced a significant decrease in perennial forb cover in 1986, largely due to a reduction in species such as pacific lupine (_Lupinus lepidus_ var. _aridus_) and American vetch (_Vicia americana_ var. _villosa_). SG on Site 1 and SU on Site 2 encountered no change in perennial forbs, while NG on Site 1 increased due to an increased cover of American vetch.

Standing crop

Species differed significantly in the amount of mean standing crop of vegetation present at the end of the grazing season (July 1) in 1986 (Table II.4). For both Site 1 and Site 2, total aboveground dry weight of plants was by far lowest in the SG treatment. The SC and NG treatments had similar levels of standing crop that were significantly higher than the SG treatment. The SU treatment had significantly more standing crop than the other treatments.

Table II.4. Mean standing crop (and standard error) for each treatment, in early July 1986.

Treatment	Standing Crop (Kg/ha)
Silviculture-Control	509.8 (26.4) a*
Native-Grazed	499.8 (42.6) a
Seeded-Ungrazed	697.0 (46.8) b
Seeded-Grazed	175.0 (35.6) c

*Means followed by similar letters are not significantly different ($p \leq 0.05$).

Discussion

The primary objective of this plantation grazing study was to improve water relations of conifer seedlings through the application of early season, intense cattle grazing. McNaughton (1982) postulated that defoliation, by decreasing total leaf surface area and transpirational losses, conserves soil moisture stores and sustains plant growth over a longer period of time. Research conducted by Svejcar and Christiansen (1987) in the southern Great Plains supports this contention. They demonstrated that soil moisture declined more slowly in heavily grazed pastures of caucasian bluestem (*Botriochloa caucasica*) compared to lightly grazed pastures.

Results of this research demonstrated that selective grazing of understory species by cattle can significantly improve the water relations of tree seedlings. Water potential measurements during the second year of this study indicated repeated, severe defoliation of seeded grasses through controlled cattle grazing, reduced understory plant vigor and consequently improved the water status of young

Douglas-fir seedlings compared to ungrazed plots (Figs. II.5 and II.6). Both predawn and midday analysis showed trees in the SG treatment with lower moisture stress than trees in the SU and NG treatments, especially early in the growing season. Seedling water potential response in the SG and SC treatments followed similar trends throughout the growing season, with treatment means on several dates not differing. This improvement in seedling water relations with grazing is consistent with results from other studies which show that use of conventional release treatments, such as herbicides, in young Douglas-fir (Cole and Newton 1986, Eissenstat and Mitchell 1983, and Preest 1975), and monterey pine (Sanandan Nambiar and Zed 1980) stands, were necessary to improve tree water potential when growing in conjunction with a grass or mixed herbaceous understory.

The lack of improvement in water stress for trees in the NG treatment may be due to several factors. Site 1 NG treatments were not grazed in 1985 due to a lack of forage, and in 1986 due to the low forage value of the plants dominating these areas. The low palatability of the forage present on Site 2 NG pastures resulted in less intensive grazing by cattle.

Livestock grazing was applied when the widespread annual grasses had already developed an inflorescence and were no longer palatable. Grazing when these grasses are vegetative and more palatable may have been more appropriate.

Soil moisture response to treatments did not correspond with water potential analysis in the second year (Fig. II.9). Grazing in the seeded areas did not significantly improve moisture conditions relative to the ungrazed counterpart. Black and Vladimiroff (1963) also found no improvement in soil moisture with grazing while Hall et al (1959) saw an increase in soil moisture at certain depths following grazing in young Douglas-fir stands. Cleary (1970) discussed the importance of measuring the extent of seedling moisture stress based on a physiological parameter, such as plant moisture stress, rather than using indirect measures such as soil moisture content. He argued that within the soil-plant-atmosphere continuum the tree was a better integrator of environmental factors influencing moisture stress, whereas single factor approaches, such as measurements of soil water, were not precise and could give misleading results.

Orchargrass and perennial ryegrass were chosen as forage species for this study because of their high palatability to livestock and ability to persist on a site once established (Heath et al 1973). The use of aggressive and opportunistic forages, such as these two species seems justified since it permitted analysis of the maximum levels of water stress to expect from conifer seedlings growing with inherently competitive plants when intact or defoliated. However, the typically low water potentials displayed by seedlings in the SU treatments would indicate that seeding of this particular forage mix in a similar environment with the exclusion of livestock grazing would create conditions of high water stress for young trees.

Analysis of total herbaceous cover, herbaceous component group cover, and total shrub cover did not support differences in water potential or soil moisture response between the four treatments (Table II.3). In contrast, Sanadan Nambiar and Zed (1980) reported cover and specific composition of weeds could be utilized as practical means of assessing the extent of water stress in young monterey pine plantations with and without weed control. Studies monitoring vegetation changes following overstory removal in the Douglas-fir region suggest logging and site preparation result in differences in the degree of disturbance on a site, and strongly influence successional trends (Dyrness 1973, Kelpsas 1978, and Kramer 1977). Differences in the intensity of broadcast burning can result in the entire vegetation on a site being composed of a mosaic of smaller vegetation units (Malavasi 1977). The resulting high variation between treatment replications, a problem in this study, reduces the ability to test for treatment differences (Kramer 1977).

The generally drier conditions on Site 2 relative to Site 1 can be traced back to the higher total herbaceous cover on this site (Table II.3). Site 2 also had a significantly greater cover of annual grasses and biennial forbs, the annual grasses depleting soil moisture reserves early in the growing season and the later growth of biennial forbs extending soil moisture removal later into the summer. Minore (1986) determined site preparation including pile and burning of Douglas-fir plantations in southwest Oregon resulted in reduced plant growth, possibly due to a degradation in site quality.

Standing crop of all vegetation was a better measure of the extent of Douglas-fir water stress when comparing the grazed and ungrazed seeded treatments (Table II.4). Although the seeded treatments and grazed treatments did not differ in the cover analyses, the SG treatment had significantly less standing crop than the SU and NG treatments, indicating establishment of palatable forages improved utilization of understory vegetation. The SC treatment had a standing crop value of no relevance to water potential response in this treatment, apparently because the application of paper mulch makes the actual standing crop level low relative to the seedling. Above and below ground biomass of vegetation within a sphere of influence around the tree may be a more appropriate measure.

Conclusion

Controlled cattle grazing in conjunction with seeding of palatable forages, resulted in Douglas-fir seedling xylem potential response similar to that for seedlings growing in a silviculture-control treatment utilizing paper mulch. Results of this research suggest controlled livestock grazing of palatable forage may be an effective silvicultural prescription for Douglas-fir plantations in southwest Oregon. Seeding without grazing is not recommended because Douglas-fir seedlings in the seeded-ungrazed treatments generally exhibited high water stress levels. More plantation grazing research is needed to explore the use of forage species which are palatable but offer minimum competition for limited site resources.

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APPENDIX

APPENDIX A: Species Cover Estimates for 1985 and 1986

Cover estimates for species in the Silviculture-control (SC), Native-grazed (NG), Seeded-ungrazed (SU), and Seeded-grazed (SG) treatments on Site 1 in 1985. Values are means ± standard errors.

SPECIES	TREATMENTS			
	SC	NG	SU	SG
Seeded species:				
Dactylis glomerata			5.2±.5	4.6±1.07
Lolium perenne			1.1±.15	1.6±0.0
Trifolium repens			0.1±.07	
T. *subterraneum*				
Perennial grass and grass-like:				
Carex multicostata	.1±.07	.1±.07	.1±.07	
Danthonia intermedia		.1±.07		
Elymus glaucus	.2±.22		.1±.07	
Luzula campestris				
Poa canadensis				
P. *pratensis*				
Stipa lemmonii				
Annual Grass:				
Aira caryophyllea				
Bromus mollis				
B. *tectorum*	.1±.14			
Vulpia megulara	.1±.14			
Perennial forbs and ferns:				
Campanula prenanthoides				
C. *scouleri*	.2±.22			.1±.07
Epilobium angustifolium				
Lotus crassifolius	.1±.07		.1±.15	
L. *micranthus*	.1±.07	.1±.07		
L. *subpinnatus*				
Lupinus lepidus var. *aridus*				
Pteridium aquilinum				
Rumex acetosella	.1±.07		.4±.29	
Vicia americana var. *villosa*	.2±.22	.4±.36	.4±.36	
Biennial Forbs:				
Cirsium arvense var. *horridum*	1.8±1.26	1.6±0.0		.2±.08
Madia madiodes	.1±.07	.1±.07	.1±.15	.1±.14
Verbascum thapsus	.4±.43	.2±.22		

Species cover estimates, Site 1, 1985, continued

SPECIES	TREATMENTS SC	NG	SU	SG
Annual Forbs:				
Collinsia grandiflora				
Collomia grandiflora				
C. heterophylla	.5±.21	.4±0.0	.6±.43	
Epilobium minutum	.1±.14			
Eriophyllum lanatum				
var. lanatum	.1±.07			
Erodium cicutarium				
Montia perfolata				
Trifolium agarium				
Shrubs:				
Apocynum androsaemifolium				
var. pumilum	.2±.16	.1±.13	<0.1	.1±.05
Berberis nervosa	.1±.14	.3±.12	<0.1	.1±.04
Ceanothus integerrimus	1.0±.08	1.7±1.4	.2±.14	.3±.18
C. prostatus		<0.1		
C. sanguineus	.2±.16	.1±.05	<0.1	<0.1
Cornus nuttalli	.2±.16		.3±.21	.5±.05
Corylus cornuta				
var. californica	.3±.25	<0.1		.4±.08
Fragaria vesca bracteata	<0.1	.1±.04		<0.1
Holodiscus discolor		<0.1		<0.1
Prunus emarginata	.1±.11			.1±.09
Rosa gymnocarpa	.2±.01	.3±.02	.1±.10	.2±.11
Rubus ursinus	.9±.40	1.2±.18	.3±.30	
Symphoricarpus albus	.7±.56	.6±.08	.8±.48	.4±.03
Whipplea modesta	.4±.45	<0.1	<0.1	.1±.12
Hardwoods:				
Acer circinatum	.1±.13	.2±.12	.2±.15	.1±.12
A. macrophyllum				
Arbutus menziesii	.2±.22			
Castanopsis chrysophylla				
Quercus garryana	.1±.10			
Q. kellogii				
Conifers:				
Pinus ponderosa		<0.1	.1±.10	<0.1
Pseudotsuga menziesii		.4±.04	.2±.04	.2±.02

Cover estimates for species in the Silviculture-control (SC), Native-grazed (NG), Seeded-ungrazed (SU), and Seeded-grazed (SG) treatments on Site 1 in 1986. Values are means ± standard errors.

	TREATMENTS			
SPECIES	SC	NG	SU	SG
Seeded species				
Dactylis glomerata			7.0±1.20	5.7±1.43
Lolium perenne			2.6±1.00	1.9±.22
Trifolium repens			.1±.07	
T. subterraneum			.3±.29	
Perennial grass and grass-like				
Carex multicostata	.1±.14	.1±.07	.1±.07	
Danthonia intermedia	.1±.14		.1±.07	
Elymus glaucus	.1±.14	.1±.07		
Luzula campestris	.1±.07			
Poa canadensis	.1±.07			
P. pratensis				
Stipa lemmonii				
Annual Grass:				
Aira caryophyllea				
Bromus mollis	.2±.22			
B. tectorum	.7±.72		.2±.22	.1±.07
Vulpia megulara	.6±.57			
Perennial forbs and ferns:				
Campanula prenanthoides				
C. scouleri				
Epilobium angustifolium				
Lotus crassifolius	.1±.14	.1±.07	.2±.22	.1±.07
L. micranthus	.1±.07			
L. subpinnatus				
Lupinus lepidus var. aridus				
Pteridium aquilinum				
Rumex acetosella			.1±.15	
Vicia americana var. villosa		.6±.64		
Biennial Forbs:				
Cirsium arvense var. horridum	4.7±2.42	9.4±1.6	1.2±.79	2.1±.57
Madia madiodes	1.1±1.07	.7±.28	.6±.22	.1±.07
Verbascum thapsus	.3±.29	.1±.07	.1±.15	.1±.07

Species cover estimates for Site 1, 1986, continued

SPECIES	TREATMENTS SC	NG	SU	SG
Annual Forbs:				
Collinsia grandiflora				
Collomia grandiflora				
C. heterophylla	.1±.07	.4±.07		
Epilobium cicutarium	.3±.29	.2±.22		
Eriophyllum lanatum var. lanatum	.1±.07		.1±.07	
Montia perfolata				
Trifolium agarium				
Shrubs:				
Apocynum androsaemifolium var. pumilum	.1±.01	.1±.05	.1±.13	.1±.04
Berberis nervosa	.2±.15	.8±.46	.2±.21	.2±.18
Ceanothus integerrimus	.3±.12	1.0±.93	.4±.06	.3±.24
C. prostatus				
C. sanguineus	<0.1	<0.1	<0.1	<0.1
Cornus nuttalli	.2±.20		.7±.28	.2±.20
Corylus cornuta var. californica	.1±.06	<0.1		.5±.07
Fragaria vesca bracteata				
Holodiscus discolor				
Prunus emarginata	<0.1	.3±.25	<0.1	
Rosa gymnocarpa	.2±.06	.2±.08	.2±.08	<0.1
Rubus ursinus	.7±.20	1.7±.17	.4±.23	<0.1
Symphoricarpus albus	.6±.42	.4±.17	.4±.13	.2±.06
Whipplea modesta	.3±.27	.3±.08	<0.1	.1±.03
Hardwoods:				
Acer circinatum	<0.1	.2±.12	.3±.30	<0.1
A. macrophyllum				
Arbutus menziesii	.2±.24			
Castanopsis chrysophylla				
Quercus garryana	.2±.15			
Q. kellogii				
Conifers:				
Pinus ponderosa			<0.1	<0.1
Pseudotsuga menziesii		<0.1		

Cover estimates for species in the Silviculture-control (SC), Native-grazed (NG), Seeded-ungrazed (SU), and Seeded-grazed (SG) treatments on Site 2 in 1985. Values are means ± standard errors.

SPECIES	TREATMENTS SC	NG	SU	SG
Seeded species				
Dactylis glomerata			2.4±1.43	3.7±.04
Lolium perenne			1.1±.64	2.2±1.79
Trifolium repens			0.1±.07	
T. subterraneum				
Perennial grass and grass-like				
Carex multicostata				
Danthonia intermedia				
Elymus glaucus	.4±.29	.4±.14	.5±.07	.5±.07
Luzula campestris				
Poa canadensis	.1±.07			
P. pratensis	.3±.29	.1±.07		
Stipa lemmonii	.1±.07		.4±.22	
Annual Grass:				
Aira caryophyllea				
Bromus mollis	.1±.15	.6±.43	.2±.03	.3±.15
B. tectorum	.9±.15	.6±.50	1.9±.79	1.0±.14
Vulpia megulara	.1±.07	.2±.01	.4±.22	.4±.22
Perennial forbs and ferns:				
Campanula prenanthoides				
C. scouleri				
Epilobium angustifolium				
Lotus crassifolius		.6±.29	.9±.86	.2±.07
L. micranthus				.4±.36
L. subpinnatus				
Lupinus lepidus var. aridus		1.0±.86		.1±0.0
Pteridium aquilinum	.8±.22		.1±.07	
Rumex acetosella	.5±.50	.6±.57	.1±.07	.2±.22
Vicia americana var. villosa	.2±.08	.4±.07		
Biennial Forbs:				
Cirsium arvense var. horridum	.6±.36		.1±.15	.6±0.0
Madia madiodes	.2±.08	2.6±2.07	3.4±1,36	1.8±.19
Verbascum thapsus	1.2±.79	2,3±1.86	.9±.29	.9±.50

Species cover estimates foe Site 2, 1985, continued

SPECIES	TREATMENTS SC	NG	SU	SG
Annual Forbs:				
<u>Collinsia grandiflora</u>		.3±.29		.9±.15
<u>Collomia grandiflora</u>		.2±.01		
C. <u>heterophylla</u>	.2±.08			.6±.65
<u>Epilobium cicutarium</u>		.1±.07	.1±.07	
<u>Eriophyllum lanatum</u> var. <u>lanatum</u>		.1±.07		
<u>Montia perfolata</u>				
<u>Trifolium agarium</u>				
Shrubs:				
<u>Apocynum androsaemifolium</u> var. <u>pumilum</u>	.1±.06	<0.1		<0.1
<u>Berberis nervosa</u>		<0.1	<0.1	<0.1
<u>Ceanothus integerrimus</u>				.2±.01
C. <u>prostatus</u>				
C. <u>sanguineus</u>		.1±.09		
<u>Cornus nuttalli</u>			<0.1	
<u>Corylus cornuta</u> var. <u>californica</u>	.1±.07	<0.1		
<u>Fragaria vesca bracteata</u>	<0.1			<0.1
<u>Holodiscus discolor</u>				<0.1
<u>Prunus emarginata</u>				
<u>Rosa gymnocarpa</u>	<0.1	<0.1		<0.1
<u>Rubus ursinus</u>	.1±.09	.1±.01	.3±.19	.2±.13
<u>Symphoricarpus albus</u>	.5±.35	.5±.47	.6±.07	.2±.01
<u>Whipplea modesta</u>				<0.1
Hardwoods:				
<u>Acer circinatum</u>				
A. <u>macrophyllum</u>				
<u>Arbutus menziesii</u>				
<u>Castanopsis chrysophylla</u>	<0.1			
<u>Quercus garryana</u>				
Q. <u>kellogii</u>				
Conifers:				
<u>Pinus ponderosa</u>		<0.1	<0.1	<0.1
<u>Pseudotsuga menziesii</u>	.1±.06	<0.1		<0.1

Cover estimates for species in the Silviculture-control (SC), Native-grazed (NG), Seeded-ungrazed (SU), and Seeded-grazed (SG) treatments on Site 2 in 1986. Values are means ± standard errors.

	TREATMENTS			
SPECIES	SC	NG	SU	SG
Seeded species				
Dactylis glomerata			3.6±1.0	4.3±.04
Lolium perenne			.5±.21	.9±.29
Trifolium repens				
T. *subterraneum*				
Perennial grass and grass-like				
Carex multicostata				
Danthonia intermedia	.4±.36	.2±.22	.6±.22	.5±.03
Elymus glaucus	.9±.57	.8±.50	.4±.29	.4±.07
Luzula campestris				
Poa canadensis		.1±.15	.1±.15	
P. *pratensis*				
Stipa lemmonii		.1±.15		
Annual Grass:				
Aira caryophyllea				
Bromus mollis	1.1±.64	.8±.22	.9±.57	.4±.36
B. *tectorum*	1.9±1.00	2.6±.43	4.2±.65	2.3±1.29
Vulpia megulara		.43±0.0	.6±.43	.2±.08
Perennial forbs and ferns:				
Campanula prenanthoides				
C. *scouleri*	.1±.07			
Epilobium angustifolium				
Lotus crassifolius	1.3±0.0	.1±.15	.6±.50	.1±.15
L. *micranthus*				
L. *subpinnatus*				
Lupinus lepidus var. *aridus*	.1±.07		.1±.07	
Pteridium aquilinum	.4±.22			
Rumex acetosella	.1±0.0	.2±.01	.2±.22	.2±.08
Vicia americana var. *villosa*	.2±.08		.1±.01	
Biennial Forbs:				
Cirsium arvense var. *horridum*	1.9±.22	3.8±.10	.9±.07	1.7±.11
Madia madiodes	2.6±.29	3.8±.08	4.9±.43	2.0±.20
Verbascum thapsus	3.9±1.22	5.9±1.93	1.7±.72	1.6±.64

Species cover estimates for Site 2, 1986, continued

SPECIES	SC	TREATMENTS NG	SU	SG
Annual Forbs:				
Collinsia grandiflora			.1±.07	
Collomia grandiflora	.1±.07			
C. heterophylla			.9±.93	
Epilobium cicutarium	.1±.07	.1±.07		.1±.07
Eriophyllum lanatum var. lanatum				.1±.07
Montia perfolata				
Trifolium agarium				
Shrubs:				
Apocynum androsaemifolium var. pumilum			.1±.04	<0.1
Berberis nervosa		.1±.10	.1±.07	
Ceanothus integerrimus				.1±.15
C. prostatus				
C. sanguineus		<0.1		
Cornus nuttalli			.1±.02	
Corylus cornuta var. californica		.2±.02		
Fragaria vesca bracteata				
Holodiscus discolor				
Prunus emarginata				
Rosa gymnocarpa		<0.1	<0.1	
Rubus ursinus	.2±.22	.1±.02	.3±.30	.1±.04
Symphoricarpus albus	.4±.37	.1±.01	.3±.17	<0.1
Whipplea modesta				.2±.02
Hardwoods:				
Acer circinatum				
A. macrophyllum				
Arbutus menziesii				
Castanopsis chrysophylla				
Quercus garryana				
Q. kellogii				
Conifers:				
Pinus ponderosa				<0.1
Pseudotsuga menziesii				<0.1