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A living mulch system consists of growing a regulated cover crop with an economic crop. Living mulches are often interplanted with horticultural crops, but competition for water can adversely affect crop production. Various management practices may limit the negative effects.

Studies were conducted for two purposes: (1) to determine if water use of perennial ryegrass (Lolium perenne L.) could be reduced by mechanical or chemical suppression, and (2) to examine water-use patterns and effects of a living mulch grown in strips between rows of Douglas fir (Pseudotsuga menziessi M.) and grand fir (Abies grandis D.) Christmas trees.

Small bucket-lysimeters were used to measure water consumption of four treatments: bareground, and mechanically suppressed, chemically suppressed, and unsuppressed perennial ryegrass, cv. Manhattan II. Sublethal rates of fluazifop-P (butyl (R)-2-[4-[[5-(trifluoromethyl)-2-pyridinyl]]oxy]phenoxy]propanoic acid) were applied to chemically suppress the grass. Evapotranspiration (ET) calculated by the Food and Agriculture Organization Blaney-Criddle method and actual ET data

were compared.

Unsuppressed ryegrass used 9% more water than ryegrass either chemically or mechanically suppressed. Bareground used 61% less water than the unsuppressed grass.

Results of the living mulch field trials indicated strips of perennial ryegrass and indigenous vegetation grown between rows of Christmas trees used more water than bareground, regardless of the suppression treatment. Measurements taken during the study indicated there were no significant differences in tree growth among treatments.

MANAGING WATER USE AND GROWTH OF A PERENNIAL RYEGRASS LIVING MULCH IN CHRISTMAS TREES

by

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To Marcus, thanks for your friendship, may the future be as good as our past history has been.

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Chapter 1

INTRODUCTION

A living mulch system consists of growing a regulated cover crop with an economic crop. Many growers in the Pacific Northwest are interested in the potential benefits of a living mulch, but they are concerned that the cover crop will use water needed to grow the economic crop, a problem that can be serious in non-irrigated crops.

Turfgrasses are often planted as living mulches. Perennial ryegrass (_Lolium_ _perenne_ L.) is recommended for planting between horticultural crop rows because it germinates quickly, establishes easily, and tolerates wear (Cook, 1982). Management practices can influence the amount of water the grass consumes. Mowing reduces water consumption of grasses (Biran et. al., 1981, Feldhake et. al., 1983), and chemical suppression has been suggested for reducing water consumption by retarding growth (Mathias, 1971).

These studies were conducted for two purposes: (1) to determine if water use of perennial ryegrass could be reduced by mechanical or chemical suppression, and (2) to examine water-use patterns and effects of a living mulch grown in strips between rows of Christmas trees.

Water consumption was measured with small bucket-lysimeters containing 4 treatments: bareground, and mechanically suppressed, chemically suppressed, and unsuppressed perennial ryegrass. Grass was chemically suppressed with a sublethal rate of fluazifop-P (butyl (R)-

2[4-[[5-(trifluoro-methyl)-2-pyridinyl]oxy]-phenoxy] propanoic acid). Actual evapotranspiration (ET) data was compared with calculated ET, determined by the Food and Agriculture Organization (FAO) Blaney-Criddle method.

Field studies at King's Valley and Cottage Grove, Oregon used gypsum blocks to monitor soil water changes from April to September 1987 in Christmas tree plantations. Four interrow treatments were imposed: bareground, strips of mechanically suppressed indigenous vegetation, and strips of perennial ryegrass either chemically or mechanically suppressed. Grass was chemically suppressed with a sublethal rate of fluazifop-P. Height, trunk caliper, and tree canopy diameter of the Christmas trees were recorded at the beginning and end of the growing season to monitor the growth response of the trees to the interrow treatments.

Chapter 2

REVIEW OF THE LITERATURE

A living mulch system consists of growing a regulated cover crop along with an economic crop. Living mulches are also referred to as sods, cover crops, and grass swards. Living mulches can be used to decrease soil erosion, increase water infiltration, limit weed invasion, and improve trafficability. Detrimental effects of living mulches may include competition for water and nutrients, and expense of establishment and maintenance. Living mulches may also provide a habitat for pests, both beneficial and harmful. Advantages and disadvantages of living mulches have been reviewed by several authors (Skroch & Shribbs, 1986, Schwendiman, 1961, Searle, 1969, Cooper, 1987, Akobundo, 1980, Peterman, 1985, Tan, 1988, Butler, 1984).

Turfgrasses are often planted as living mulches. Perennial ryegrass is recommended for planting between horticultural crop rows in the Willamette Valley because it germinates quickly, establishes easily, tolerates wear, and is a bunch grass (Cook, 1982).

While many growers are interested in the potential benefits of a living mulch there is concern that the cover crop will use water needed to grow the economic crop (William, 1984). This is especially a concern to growers of non-irrigated crops, as water availability is often the most limiting factor to optimum crop growth.

GRASS WATER USE

The water content of actively growing turfgrasses varies from 75 to 85% by weight (Beard, 1973, Shearman, undated). Roots are the primary pathway of water uptake for most plants. According to Beard (1973) uptake of water by turfgrasses is related to the depth of the root system, available soil water in the root zone, number of roots, root elongation rate, soil temperature, and evaporative demand.

Transpiration is the water lost by the plant through the cuticle or the stomates to the atmosphere. Transpirational losses are primarily through the leaves but may occur through any plant part exposed to the atmosphere. The main benefit of transpiration is the cooling effect resulting from the evaporative process. This affect is especially beneficial to the cool season grasses (Beard, 1973). Transpiration also influences plant metabolic processes, and can become detrimental when it exceeds water uptake rates.

Evaporation is the loss of water, from the liquid to the vapor phase, from an open water source or wet soil surface by physical processes. Evapotranspiration is the combined loss of water from transpiration and evaporation. Evapotranspiration rates reach maximum levels in the summer months (Kramer, 1969, Pruitt, 1964).

Turfgrass water-use rate is the amount of water required for growth plus the amount evapotranspired. Under normal conditions water-use rate by turfgrasses is 2.5 to 7.6 mm/day (Beard, 1973). The ET rate from turf is much greater than the evaporation rate from a bare soil (Beard, 1973), although, under well-watered conditions, soil type has little effect on ET rates (Biran, 1981).

Water consumption is reduced after mowing (Weaver, 1941, Madison, 1962, Sadamori, 1955, Mitchell & Kerr, 1966). Decreasing mowing height decreases water consumption (Biran, 1981, Feldhake et al., 1984, Madison, 1962). Cutting with a dull mower results in injury to the remaining leaf tissues and increases water-use rates (Beard, 1973).

Summer dormancy, a condition where growth is limited or completely ceases, is characteristic of many turfgrass species and is closely related to water availability. Laude (1953) studied growth response to water supplied in summer to perennial ryegrass and other turfgrasses. Vegetative growth of ryegrass continues as long as moisture is available, after which the grass goes dormant. Growth resumes when water is applied.

Chemical suppression has been suggested as a means of reducing water consumption by retarding plant growth. Mathias (1971) studied the effect of two growth-regulating chemicals on yield and water use of three perennial grasses. Cycocel (2-chloroethyltrimethylammonium chloride) is effective in nearly ceasing grass growth, and F-529 (N-pyrrolidinosuccinamic acid) reduces grass growth to 35% of the control.

Fluazifop-P (butyl (R)-2[4-[[5-(trifluoromethyl)-2-pyridinyl] oxy]] phenoxy] propanoate) is a postemergence herbicide used for the control of annual and perennial grasses in many orchards and horticultural crops (Burrill et. al., 1988). It inhibits meristematic growth and at sublethal rates suppresses growth of perennial ryegrass for several weeks (William & Brenner, 1985, Warren, 1986, Skroch & Schribbs, 1986). Wiles (1986) found one sublethal application of fluazifop-P reduces perennial ryegrass dry weight in both field and greenhouse studies.

Cultural practices such as mowing and chemical suppression can be an effective means of lowering water consumption of grasses. These two practices may be useful tools in living mulch systems to lower water consumption of the grass.

LYSIMETRY

Determining crop water requirements can be accomplished through a variety of calculations or by field and lab measurements (Doorenbos & Pruitt, 1984, Hillel, 1982, Kramer, 1969, Squire, 1981). The most direct measurement of the field water balance is through the use of lysimeters (Aboukhaled, 1982, Black, 1968, Doorenbos, 1984, Harrold & Dreibelbis, 1958, Harrold, 1968, Hillel, 1982, Pruitt, 1964, van Bavel, 1962).

Types of lysimeters fall into two general categories: weighing and non-weighing. Doorenbos and Pruitt (1984) provide an extensive summary of the use and installation of lysimeters.

Lysimeters should be used in conjunction with other methods of determining ET or crop water use under field conditions (Aboukhaled, et. al., 1982). In 1985, a field experiment at the Oregon State University (OSU) Vegetable Research Farm was conducted to evaluate six semi-empirical methods of estimating evapotranspiration. Of the six methods evaluated, Smith (1986) found the FAO Blaney-Criddle method to be the most accurate. A 14 year study by Burman et. al. (1983) compared lysimeter-measured ET with the Soil Conservation Service (SCS) and FAO Blaney-Criddle methods for alfalfa. The FAO Blaney-Criddle estimate was nearly identical to the measured ET, while the SCS Blaney-Criddle underestimated the lysimeter ET measurements by 25 to 30%. The FAO Blaney-Criddle method calculates ET using this equation (Doorenbos and Pruitt, 1984):

$$ET_r = a + b\ [p\ (0.46T + 8.13)]$$

where: ET_r = reference crop ET for grass, mm/day

p = % annual sunshine during month on a daily basis

T = mean temperature, ^{o}C

a, b = climatic calibration coefficients (minimum relative humidity, daytime wind velocity, and ratio of actual to maximum possible sunshine hours)

INFLUENCE OF VEGETATION ON CHRISTMAS TREE GROWTH

Drought is a primary cause of failure in new Christmas tree plantations. Douglas fir trees can tolerate substantial moisture stress without serious long-term interference of metabolic processes but limited root elongation results (Newton, 1965). For these reasons it is generally recommended Christmas tree growers keep their plantations free of vegetation. Recently, Christmas tree growers in the Pacific Northwest have expressed an interest in using living mulches to decrease soil erosion and improve trafficability (William et.al., 1982).

Larson and Schubert (1969) studied the effects of two grasses on root and shoot growth of ponderosa pine seedlings. Seedlings were grown in monocultures or with grass. Root and shoot growth of the pines was significantly reduced by the presence of Arizona fescue (Festuca arizonica), a cool season grass. Grass depleted soil moisture faster and to lower levels than pine seedlings alone. The only pines that survived the 2 year study were those with a root system at least 40 cm below the soil surface where soil moisture remained high regardless of treatment.

Reynolds (1970) studied root distribution of 36 year old Douglas fir trees. A volumetric core tool was used to randomly sample root length and spatial variability. Results of the study indicate the majority of Douglas fir roots are concentrated in the 0 to 46 cm range of soils, with the 0 to 15 cm zone containing twice times as many roots as any other zone.

Atkinson (1980) reviewed the distribution and effectiveness of tree roots under multiple conditions. He notes that spread of the root system of orchard trees grown with a grass alley and a herbicide strip in the tree row results in a greater number of roots concentrated under the herbicide strip. Atkinson further notes that the roots of young trees are primarily located near the trunk so little use is made of the area outside the herbicide strip.

Little has been done to examine the interaction of Christmas trees and managed vegetation in plantation settings. Much remains to be learned about competition and growth under strips of vegetation and a variety of environmental conditions.

Chapter 3

INFLUENCE OF CHEMICAL, MECHANICAL AND NO SUPPRESSION ON WATER CONSUMPTION OF PERENNIAL RYEGRASS

MATERIALS AND METHODS

Perennial ryegrass, cv. Manhattan II, was seeded into 3.75-liter plastic buckets on 28 May 1987. Two screened 14-mm holes in the bottom of each bucket allowed drainage. The buckets were placed in a greenhouse mist chamber for 5 days to encourage uniform germination. The buckets were then moved outside for 3 weeks before being moved to the experimental site at the Oregon State University Vegetable Research Farm east of Corvallis, Oregon. Buckets were installed in the field as shown in Figure 3.1. The potting mixture was sand, soil, peat, and pumice in a ratio of 1:1:1:2. Twenty-four buckets contained grass and slow-release pellets of $N\text{-}P_2O_5\text{-}K_2O$ (14-14-14). The buckets designated as bareground contained potting mix only. The experiment used a completely randomized design with each treatment replicated eight times, for a total of 32 plots. Each bucket-lysimeter was placed in the center of a one meter square area maintained in the same manner as the treatments in the buckets.

Initially, all plots and buckets with grass were mowed to 6.4 cm. Fluazifop-P at 0.22 kg/ha was then applied to the chemical-suppression treatment areas. Mechanically suppressed grass was allowed to grow 2 to 2.5 cm before being mowed back to 6.4 cm, for a total of three mowings during the 6-week study. Grass in plots with no suppression was allowed to grow unchecked. Bareground areas were maintained free of vegetation by hoeing.

Evapotranspiration was measured from 6 August to 14 September

1987. Buckets were weighed every 2 to 3 days. When irrigation was necessary, buckets were removed from the field and weighed, then watered to saturation and allowed to drain for 12 hours. Buckets were watered in the evening so they could be returned to the field in the early morning. The field plots were sprinkler-irrigated at night while the buckets were draining. After draining, buckets were again weighed, the holes were plugged to prevent water from draining, and the buckets were returned to the field. All changes in weight could then be attributed to evaporation or transpiration.

A weather station 600 meters from the experiment site recorded minimum and maximum temperature, wind run, relative humidity, solar radiation, and precipitation every half-hour. These data were converted to 12 hour averages. The average temperature, minimum relative humidity, and wind run data were then used to calculate ET by the FAO Blaney-Criddle method using a computer program (Doorenbos & Pruitt, 1984, Braunworth, unpublished). Actual and calculated ET values were compared.

RESULTS AND DISCUSSION

Unsuppressed ryegrass used 9% more water than ryegrass either chemically or mechanically suppressed. Bareground used 61% less water than the unsuppressed ryegrass (Table 3.2). The average measured and calculated ET from 4 August to 14 September 1987 is shown in Figure 3.2.

Water use by the chemically and mechanically suppressed ryegrass was not significantly different. Bareground used substantially less water than all other treatments. The water-use rate of turf is much greater than that of bare soil (Welton, 1938). Beard (1973) reports the water-use rate of turfgrasses is 2.5 to 7.5 mm/day and results of this lysimeter study support these data. Studies suggest water use of grass is decreased by chemical suppression (Mathias et. al. 1971, Trimmer and Linscott, 1985). Wiles (1987) found mowing generally not as effective in maintaining yield as chemical suppression in a trial with vegetables and an annually planted perennial ryegrass living mulch. If the competitive ability of a living mulch is a function of water use, the leaf area and its duration suggest a mechanically suppressed mulch would be less competitive than an unsuppressed mulch (Wiles, 1987). Sadamori (1955) notes the interval between mowings influences the water-use rate of turfgrasses. Results of this experiment might have been different if mowing had been at either shorter or longer intervals.

Results of this study indicated one application of fluazifop-P or three mowings in a 6-week period were cultural methods that reduced the evapotranspiration and water use of perennial ryegrass. The FAO Blaney-Criddle method over-estimated water use of the chemically suppressed grass by 6%, of the mechanically suppressed grass by 5%, and under-estimated water use of the unsuppressed grass by 5% (Table 3.2).

Further research of cultural practices affecting crop yield and water use of living mulches is needed. Chemical and mechanical suppression of grass should be investigated under diverse environmental conditions as well. An improved understanding of the factors affecting crop yield and water use by both the crop and the living mulch will enable growers to more efficiently manage water resources.

Table 3.1. Average daily and total evapotranspiration (ET) from bareground, and perennial ryegrass with three suppression treatments from 4 August to 14 September 1987.

Treatment	**Average ET (mm water)**	
	Daily	Total
Bareground	2.15	88.25
Chemically suppressed	4.99	204.58
Mechanically suppressed	5.01	205.72
Unsuppressed	5.52	226.19
LSD (0.01)	0.46	18.91

Table 3.2. Percent difference between cumulative evapotranspiration (ET) values from 4 August to 14 September 1987 for perennial ryegrass with three suppression treatments, and the FAO Blaney-Criddle (FAO BC) method of estimating ET.

Treatment	Actual ET (mm)	FAO BC (mm)	Percent difference
Chemical sup.	204.58	215.97	-5.56
Mechanical sup.	205.72	215.97	-4.98
Unsuppressed	226.19	215.97	+4.52

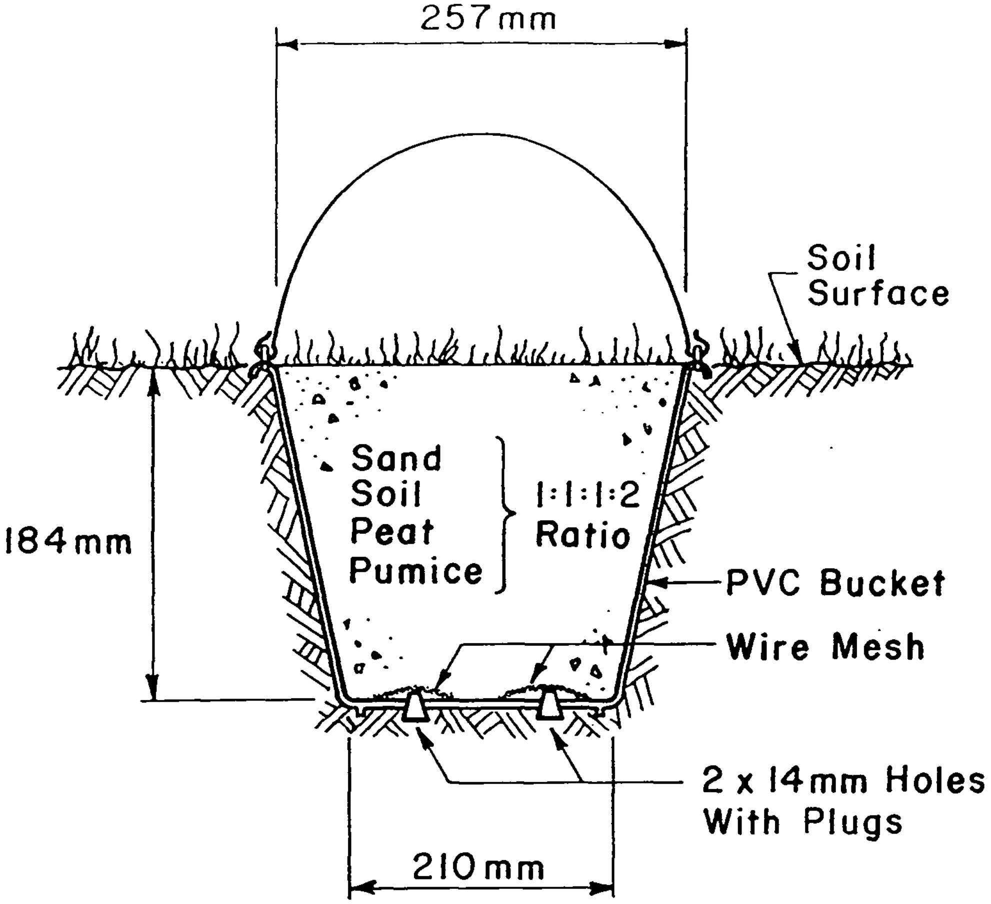

Figure 3.1. Profile of a bucket-lysimeter installed in the field.

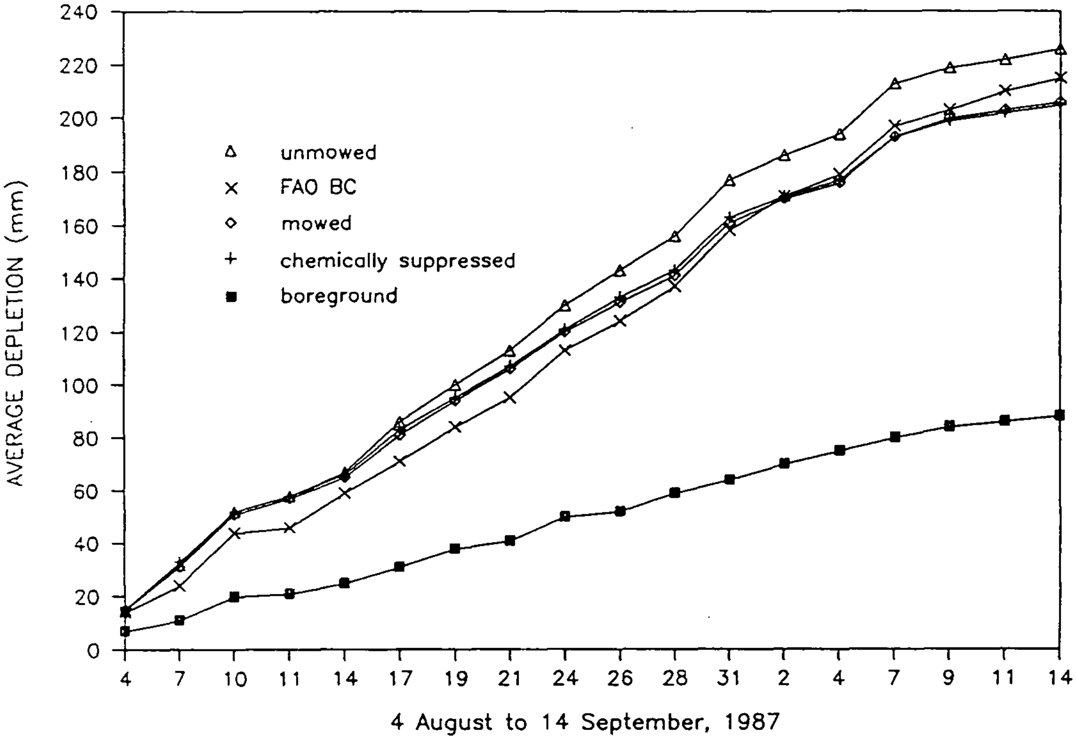

Figure 3.2. Average cumulative water depletion in 1987 measured with bucket-lysimeters, and ET calculated by the FAO Blaney-Criddle method.

Chapter 4

MANAGING WATER USE AND GROWTH OF A PERENNIAL RYEGRASS LIVING MULCH IN CHRISTMAS TREES

MATERIALS AND METHODS

King's Valley Field Trial

Douglas fir (Pseudotsuga menziesii M.) Christmas trees were planted at the Sunrise Tree Farm near King's Valley, Oregon in October 1985. The trees were planted about 0.8 m apart in the tree row with 1.8 m between rows. The soil is an Abiqua silty clay loam with no slope.

'Manhattan II' perennial ryegrass was seeded at 22.4 kg/ha in 0.9 m strips between tree rows in November 1985. A 0.9 m wide strip was left with no grass planted in the tree row.

Research plots 3.65 m wide by 6.1 m long were established in April 1986. The plots were arranged in a randomized complete block design. Three interrow treatments were imposed on 16 plots: four plots with bareground, four plots with 0.9 m wide strips of indigenous vegetation, and eight plots with 0.9 m wide strips of 'Manhattan II' perennial ryegrass. The plots designated to be bareground and indigenous vegetation were sprayed with 1.68 kg/ha glyphosate (N-(phosphonomethyl) glycine) to kill the previously planted perennial ryegrass. Bareground treatment areas and the 0.9 m wide strip in the tree row were maintained free of vegetation by a combination of hand hoeing and herbicides. After the initial glyphosate application, indigenous vegetation plots were not sprayed. During the 1987 growing season the 0.9 m wide strip in the indigenous vegetation plots had plants covering about 80% of the soil surface (see Appendix A). All plots with vegetation were mowed periodically from June through September, 1986.

During the 1987 growing season, half of the plots with strips of perennial ryegrass were mechanically suppressed, while the remaining four were chemically suppressed with a sublethal rate of fluazifop-P. Indigenous vegetation and mechanically suppressed ryegrass strips were mowed to 6.4 cm on 9 April, 3 June, and 25 June. Chemically suppressed strips of ryegrass received two applications of 0.22 kg/ha fluazifop-P plus 1% (v/v) crop oil (Mor-act adjuvant) on 15 April and again on 20 May. Two to 3 days prior to both of the herbicide applications grass was mowed to 6.4 cm. All plots with vegetation were mowed to 6.4 cm on 6 August.

In April 1986, gypsum blocks were installed at 30, 60, and 90 cm depths in two locations in each plot: one set in the tree row between two trees, and the other set placed mid-way between tree rows. Gypsum blocks were not monitored during the 1986 growing season, although interrow treatment areas were maintained as previously mentioned. On 30 April 1987 two additional sets of blocks per plot were installed at 15, 30, 60, and 90 cm depths: one set about 8 cm from a tree in the tree row, and a second set mid-way between tree rows. Additionally, blocks were installed at 15 cm depths in locations which previously had only three blocks (30, 60, and 90 cm depths) resulting in a total of 16 blocks per plot and 256 blocks for the entire experiment. Gypsum blocks were monitored 11 times, approximately every 2 weeks, from 20 May to 2 September 1987.

Gypsum block locations were divided into three groups for data analysis: (1) the two sets located between tree rows, (2) the set next to a tree, and (3) the set in the tree row between two trees. Gypsum block readings were converted to matric potential with a computer program (Braunworth & Cuenca, unpublished) using the manufacturer's calibration curve.

Height, trunk caliper, and tree canopy diameter were recorded on 27 March and 2 September 1987 to monitor the growth response of the trees to the interrow treatments. Canopy volume was calculated using the height and tree canopy diameter measurements.

All data were analyzed by analysis of variance. Mean separation, Least Significant Difference (LSD), was used to compare differences in the gypsum block measurements.

Cottage Grove Field Trial

Grand fir (Abies grandis D.) Christmas trees were planted in Cottage Grove, Oregon in April 1986 on a McAplin silty clay loam soil with no slope. Trees were planted 1.2 m apart in the tree row and 1.8 m between rows.

'Manhattan II' perennial ryegrass was seeded at 22.4 kg/ha in 0.9 m wide strips between tree rows in April 1986. A 0.9 m wide strip was left with no grass planted in the tree row.

Research plots 3.65 by 4.6 m, with four trees per plot, were established in May 1986. The plots were arranged in a randomized complete block. Three interrow treatments were imposed on 16 plots: four plots with bareground, four plots with 0.9 m wide strips of indigenous vegetation, and eight plots with 0.9 m wide strips of 'Manhattan II' perennial ryegrass. The plots designated to be bareground and indigenous vegetation were sprayed with 1.68 kg/ha glyphosate to kill the previously planted perennial ryegrass. Bareground treatment areas and the 0.9 m wide area in the tree row were maintained free of vegetation by a combination of hand hoeing and herbicides. After the initial glyphosate application indigenous vegetation plots were not sprayed. During the 1987 growing season the 0.9 m wide strip in the indigenous vegetation plots had plants covering about 70% of the soil surface (see Appendix A). All plots with vegetation were mowed periodically from June to September 1986.

During the 1987 growing season, half of the plots with strips of perennial ryegrass were mechanically suppressed, while the remaining four were chemically suppressed with a sublethal rate of fluazifop-P. Indigenous vegetation and mechanically suppressed ryegrass strips were mowed to 6.4 cm on 16 April, 15 May, and 23 June 1987. Chemically suppressed strips of ryegrass received 0.22 kg/ha fluazifop-P plus 1% (v/v) crop oil (Mor-act adjuvant) on 16 April and again on 22 May. Two to 3 days prior to both of the herbicide applications grass was mowed to 6.4 cm. All plots with vegetation were mowed to 6.4 cm on 7 August.

Gypsum blocks were installed on 13 May 1986 at 30, 60, and 90 cm depths in the following locations: mid-way between rows in all four treatment plots, and between two trees in the row of the mowed and indigenous vegetation plots for a total of 72 blocks in the experiment. The blocks were not monitored during the 1986 growing season although interrow treatment areas were maintained as previously mentioned. In 1987 gypsum blocks were read 11 times from 16 April to 5 September.

Gypsum block locations were divided into two groups for data analysis: (1) the set located between tree rows (all four treatments), and (2) the set located between two trees in the tree row (in the mechanically suppressed ryegrass and indigenous vegetation plots). Gypsum block readings were converted to matric potential with a computer program (Braunworth & Cuenca, unpublished) using the manufacturer's calibration curve.

Height, trunk caliper, and tree canopy diameter were recorded on 8 April and 9 September 1987 to monitor the growth response of the trees to the interrow treatments. Canopy volume was calculated using the height and tree canopy diameter measurements.

All data were analyzed by analysis of variance. Mean separation, Least Significant Difference (LSD), was used to compare differences in the gypsum block measurements.

RESULTS AND DISCUSSION

King's Valley Field Trial

A significant treatment by location effect on soil water potential was detected for the 15, 60, and 90 cm depths; no significant interaction was noted at the 30 cm depth (Table 4.1). More water was used in the tree row of the bareground plots than in the interrow areas at the 15 and 30 cm depths, the main rooting zone of the trees. Differences at the two deeper depths were not apparent in plots with bareground (Figure 4.1). Plots with vegetation tended to have a lower matric potential (less soil water available) in the interrow areas compared to the matric potentials in the tree row (Figures 4.2, 4.3, and 4.4). These data also indicated that plots with vegetation between tree rows drew water from deeper depths than plots with no vegetation.

The treatment by location data indicated the young Douglas fir Christmas trees primarily took up water from a small area directly around the tree trunk, indicating a fairly compact root system in the early years. Reynolds (1970) notes the vertical spread of 36 year old Douglas fir tree roots is 1.1 m, with the top 15 cm containing twice the density of roots as the lower depths. He also notes a greater root length, but not density, in the 15 to 46 cm zone of soil.

Gypsum block readings showed a significant treatment by date interaction for all four depths (15, 30, 60, and 90 cm). Results are shown in Table 4.2. More soil water was available in the bareground plots at all gypsum block locations during the majority of the experiment's duration. Differences between the three vegetation treatments were less pronounced. It appeared that plots with vegetation drew water from at least 90 cm depths, and possibly deeper (Table 4.1). Water loss in the bareground plots was primarily confined to the upper 30 cm of the soil.

An unusual summer weather front resulted in 5.3 cm of precipitation from the 17th to the 20th of July (see Appendix B - Summit, Oregon) allowing the 15 and 30 cm depths of all plots to reach "field capacity" (Table 4.2). Block readings made 2 weeks later noted a substantial increase in soil water potential at the 15 and 30 cm depths in all plots with vegetation.

Data indicated blocking was not effective in reducing experimental error.

Measurements taken during this study indicated there were no significant differences in tree growth between any of the treatments. Trees grew an average of 30 cm in height, 8.4 mm in trunk caliper, and 12,352 cm^3 in canopy volume (Table 4.3).

Cottage Grove Field Trial

A treatment by date interaction effect on interrow soil water potential at the 30 cm depth was noted (Table 4.4). Bareground plots showed a substantially higher matric potential (more soil water available) between tree rows indicating available soil water at the 30 cm depth. Soil water potential at the 30 cm depth in plots with vegetation was lower than in the bareground plots.

Interrow gyspum block measurements noted a significant treatment effect at the 60 and 90 cm depths (Table 4.5). Bareground used significantly ($p = 0.01$) less water than any treatment at the 60 cm depth. At the 90 cm depth both the bareground and the chemically suppressed ryegrass plots had a lower matric potential than the mechanically suppressed ryegrass and indigenous vegetation.

Gypsum block measurements in the tree row showed a significant difference between the mechanically suppressed ryegrass and the indigenous vegetation at the 30 and 90 cm depths; no significant difference was noted at the 60 cm depth (Table 4.6). Mechanically suppressed ryegrass had an average soil matric potential of -38 kPa, while the indigenous vegetation soil matric potential averaged -165 kPa, indicating a higher water availability in the tree row of plots with mechanically suppressed ryegrass. Matric potential of -168 kPa indicated soil water was available for uptake by plants and the significant difference could be attributed to tree rooting differences in the plots and not exclusively to the effects of the interrow treatments.

Data indicated blocking was effective.

Measurements taken during this study indicated there were no significant differences in tree growth between any of the treatments. Trees grew an average of 9.75 cm in height, 3 mm in trunk caliper, and 3965 cm^3 in canopy volume (Table 4.7).

Summary

This study examined the effect of a living mulch on Christmas tree growth during the early years of the production cycle. While water use patterns under the four management regimes differed, Christmas tree growth was not affected during the duration of the study. The information in these studies on the interaction of a living mulch and Christmas trees is insufficient to determine the long-term effects on Christmas tree growth and quality. Studies should be conducted to examine the effects of a living mulch on Christmas tree growth and quality over an entire tree production cycle. Management of the grass may become a more important factor as the tree root system expands and draws water from a larger area. If a living mulch reduces tree growth only later in the production cycle, some of the benefits of a living mulch could be obtained by killing the sod when interference with crop growth becomes critical.

The competitive advantage of perennial ryegrass against the invasion of deep-rooted grasses and broad leaf weeds under mechanical and chemical suppression should be fully investigated. Grass mechanically suppressed may prove to use less water than grass chemically suppressed if the post-emergence grass herbicides used for chemical suppression stunt perennial ryegrass growth enough to allow undesirable vegetation to become established.

There is no reported research indicating what the critical width of the bareground strip in the tree row should be. The current recommendation is that one-third to one-half the area between tree rows should remain free of vegetation. This should be investigated in a long-term study to determine if this recommendation is the best.

Another question this study raises is the feasibility of using indigenous vegetation as living mulch. From this study it could be concluded that it is a potentially good living mulch; however, the use of it may lead to increased vertebrate pest problems, an increase in the number of deep-rooted perennial weeds, and problems with the spread of weed seeds to areas surrounding the field.

Table 4.1. Treatment and location effect on soil water potential (-kPa) as measured by gypsum blocks at the King's Valley site. Averaged from 20 May to 18 September 1987.

		Treatment[3]			
Depth[1]	Location[2]	1	2	3	4
		(-kpa)			
	A	606	781	751	788
15 cm	B	475	478	754	628
	C	240	1069	1037	987
	A	258	347	433	336
30 cm	B	88	138	277	345
	C	91	957	930	892
	A	52	139	586	279
60 cm	B	50	107	265	84
	C	32	906	923	827
	A	32	120	229	150
90 cm	B	33	67	202	105
	C	33	612	584	820

[1] Mean separation within each depth:
15 cm means are significantly different at $p = 0.05$, LSD (0.05) = 321.
30 cm means are not significantly different.
60 cm means are significantly different at $p = 0.05$, LSD (0.05) = 372.
90 cm means are significantly different at $p = 0.01$, LSD (0.05) = 266.

[2] Location:
A = next to a tree, in the tree row
B = between two trees, in the tree row
C = mid-way between tree rows

[3] Treatment numbers:
1 = Bareground
2 = Chemically suppressed grass
3 = Mechanically suppressed grass
4 = Mechanically suppressed indigenous vegetation

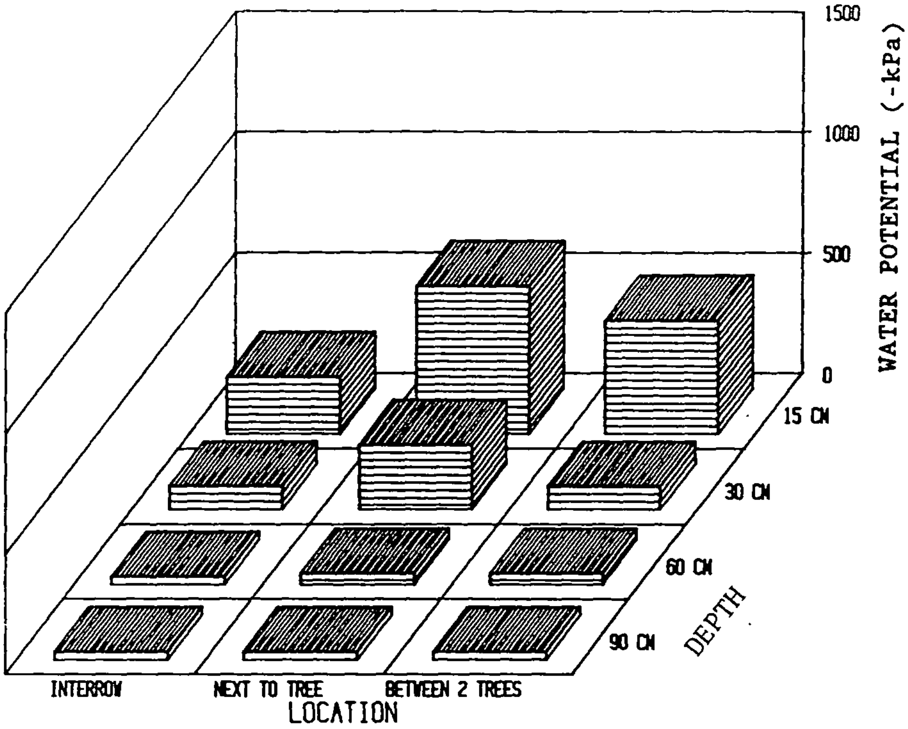

Figure 4.1. Seasonal average water potential (-kPa) as measured by gypsum blocks in King's Valley in the bareground plots.

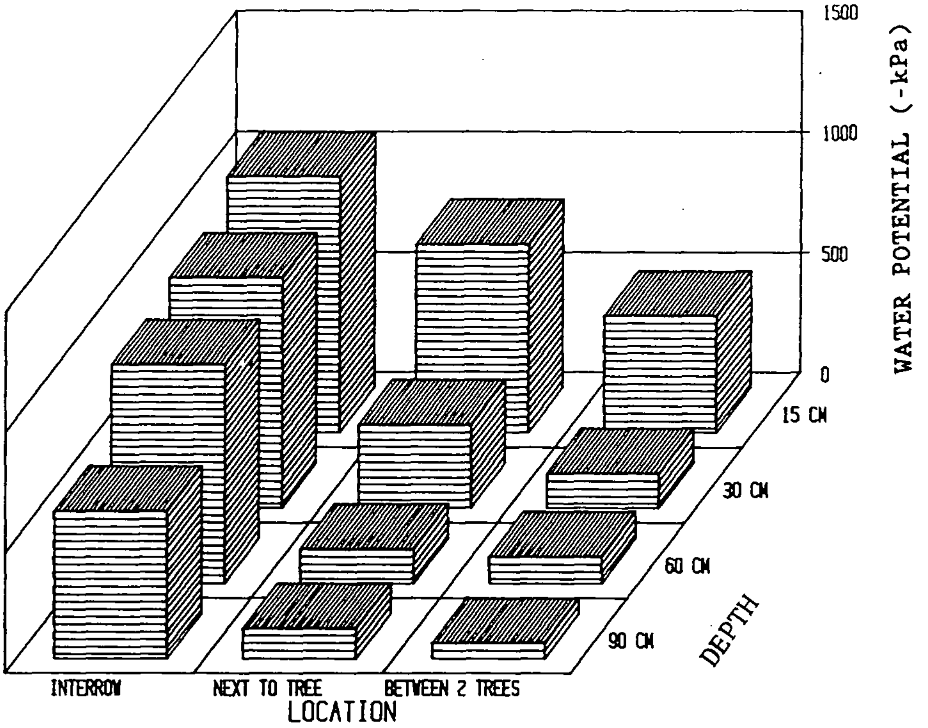

Figure 4.2. Seasonal average water potential (-kPa) as measured by gypsum blocks in King's Valley in the chemically suppressed perennial ryegrass plots.

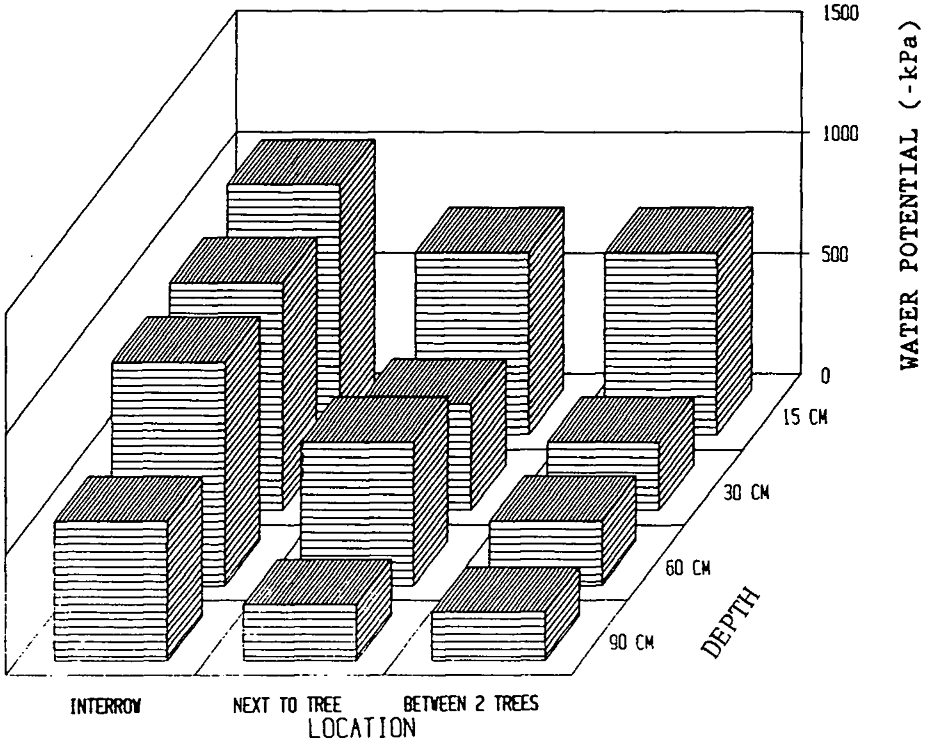

Figure 4.3. Seasonal average water potential (-kPa) as measured by gypsum blocks in King's Valley in the mechanically suppressed perennial ryegrass plots.

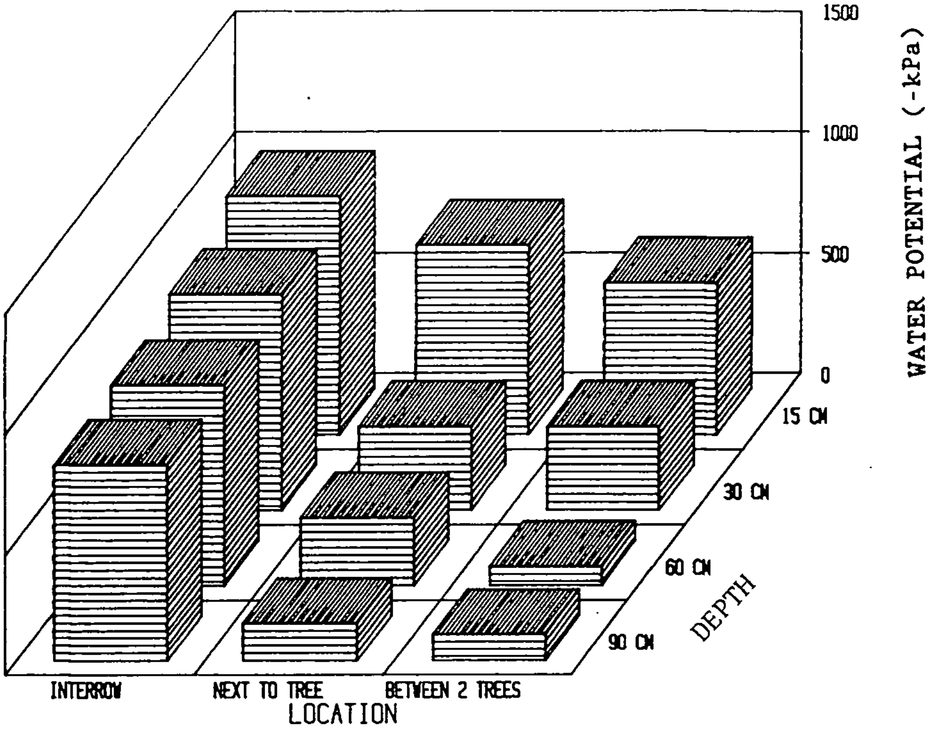

Figure 4.4. Seasonal average water potential (-kPa) as measured by gypsum blocks in the King's Valley in the mechanically suppressed - indigeneous vegetation plots.

Table 4.2. Treatment and date effect on soil water potential (-kPa) as measured by gypsum blocks at the King's Valley site, 15, 30, 60, and 90 cm depths. Averaged from all block locations, 20 May to 18 September 1987.

		Treatment[2]			
Depth[1]	Date	1	2	3	4
		(-kPa)			
15 cm	May 20	65	720	694	490
	May 29	47	71	128	85
	June 4	56	42	54	105
	June 17	155	951	951	1055
	July 2	488	1146	1071	1229
	July 16	922	1311	1254	1355
	July 21	32	34	33	38
	August 5	63	854	957	848
	August 19	528	1253	1285	1281
	September 2	878	1319	1340	1418
	September 18	1052	1387	1371	1418
30 cm	May 20	43	70	227	248
	May 29	43	33	39	61
	June 4	40	148	264	282
	June 17	61	742	841	690
	July 2	153	818	919	919
	July 16	198	852	957	972
	July 21	39	33	33	37
	August 5	57	501	537	341
	August 19	164	878	972	836
	September 2	254	997	1092	1075
	September 18	396	1188	1285	1314
60 cm	May 20	32	32	123	35
	May 29	32	32	119	32
	June 4	32	54	184	218
	June 17	32	298	517	432
	July 2	33	619	925	714
	July 16	33	726	988	815
	July 21	32	216	556	252
	August 5	32	563	955	439
	August 19	32	759	990	742
	September 2	46	855	1004	866
	September 18	121	1054	1055	1003

Table 4.2 (continued)

90 cm	May 20	31	32	32	32
	May 29	32	32	32	32
	June 4	32	32	32	51
	June 17	32	38	77	226
	July 2	33	267	318	352
	July 16	33	315	442	474
	July 21	32	219	437	362
	August 5	32	298	534	505
	August 19	32	498	706	653
	September 2	32	578	846	848
	September 18	32	794	940	875

---

[1] Mean separation within each depth:
Means are significant at $p = 0.01$
15 cm LSD (0.05) = 219
30 cm LSD (0.05) = 275
60 cm LSD (0.05) = 223
90 cm LSD (0.05) = 273

[2] Treatment numbers:
1 = Bareground
2 = Chemically suppressed grass
3 = Mechanically suppressed grass
4 = Mechanically suppressed indigenous vegetation

Table 4.3. Average growth of Douglas fir Christmas trees in King's Valley from 27 March to 2 September 1987.

Treatment	Seasonal Growth		
	Height (cm)	Trunk caliper (mm)	Canopy volume (cm^3)
(1) Bareground	30.2	9.2	13,364
(2) Chemically suppressed ryegrass	29.5	7.7	11,507
(3) Mechanically suppressed ryegrass	31.5	9.2	12,757
(4) Mechanically suppressed indigenous vegetation	27.4	7.8	12,233

Standard errors:	Caliper	Height	Canopy volume
Treatment (1)	0.56	2.01	1457
(2)	0.54	1.93	1402
(3)	0.54	1.93	1402
(4)	0.59	2.14	1553

Table 4.4. Treatment and date effect on soil water potential (-kPa) as measured by gypsum blocks located between tree rows at the Cottage Grove site, 30 cm depth. Averaged from 16 April to 5 September 1987.

	Treatment[2]			
Date[1]	1	2	3	4
	(-kPa)			
April 16	33	33	52	41
May 15	37	630	730	58
May 22	41	892	1073	501
May 31	57	1190	1077	691
June 6	48	1418	1079	944
June 13	41	1418	1418	1418
July 7	59	1418	1418	1418
July 24	30	414	724	376
August 7	32	1133	1073	804
August 22	30	1418	1091	1230
September 5	32	1418	1418	1071

[1] Mean separation within each depth:
Means are significant at $p = 0.05$.
LSD (0.05) = 539

[2] Treatment numbers:
1 = Bareground
2 = Chemically suppressed grass
3 = Mechanically suppressed grass
4 = Mechanically suppressed indigenous vegetation

Table 4.5. Treatment effect on soil water potential (-kPa) as measured by gypsum blocks located between tree rows at the Cottage Grove site, 60 and 90 cm depths. Averaged from 16 April to 5 September 1987.

	Treatment[2]			
Depth[1]	1	2	3	4
	(-kPa)			
60 cm	37	626	535	747
90 cm	35	53	207	303

[1] Mean separation within each depth:
Means are significant at $p = 0.01$.
60 cm LSD (0.05) = 274
90 cm LSD (0.05) = 124

[2] Treatment numbers:
1 = Bareground
2 = Chemically suppressed grass
3 = Mechanically suppressed grass
4 = Mechanically suppressed indigenous vegetation

Table 4.6. Treatment effect on soil water potential (-kPa) as measured by gypsum blocks located in the tree row at the Cottage Grove site, 30, 60, and 90 cm depths. Averaged from 16 April to 5 September 1987.

	Treatment[2]	
Depth[1]	1	2
	(-kPa)	
30 cm	32	168
60 cm	39	128
90 cm	44	198

[1] Mean separation within each depth:
30 cm means are significantly different at $p = 0.05$, LSD (0.05) = 112.
60 cm means are not significantly different.
90 cm means are significantly different at $p = 0.05$, LSD (0.05) = 124.

[2] Treatment numbers:
1 = Mechanically suppressed grass
2 = Mechanically suppressed indigenous vegetation

Table 4.7. Average growth of grand fir Christmas trees in Cottage Grove from 8 April to 9 September 1987.

Treatment	Seasonal Growth		
	Height (cm)	Trunk caliper (mm)	Canopy volume (cm^3)
Bareground	9.8	3.9	3931
Chemically suppressed ryegrass	9.8	3.2	3992
Mechanically suppressed ryegrass	10.1	2.1	3998
Mechanically suppressed indigenous vegetation	9.3	2.9	3940

Standard error:	Height	Caliper	Canopy volume
All Treatments	0.84	0.44	581

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APPENDICES

APPENDIX A

Plant species in indigenous vegetation plots

King's Valley:

Bellis perennis (English daisy)
Cirsium vulgare (bull thistle)
Daucus carota (wild carrot)
Erodium cicutarium (filaree)
Festuca arundinacea (tall fescue)
Hypericum perforatum (St. Johnswort)
Lolium perenne (perennial ryegrass)
Vicia angustifolia (vetch)

Cottage Grove:

Daucus carota (wild carrot)
Erodium cicutarium (filaree)
Festuca arundinacea (tall fescue)
Lolium perenne (perennial ryegrass)
Rubus spp. (blackberry)

APPENDIX B

1987 Weather Data

WEATHER DATA, 1987

Corvallis, Oregon

	July			August			September		
Day	Daily Precip. Inches	Temp. °F Max.	Temp. °F Min.	Daily Precip. Inches	Temp. °F Max.	Temp. °F Min.	Daily Precip. Inches	Temp. °F Max.	Temp. °F Min.
1		89	56		76	52		101	53
2		81	55		81	49		95	46
3		76	48		87	54		77	46
4		74	56		95	52		77	49
5	.04	71	52		89	51		85	56
6	T	72	44		80	49		93	49
7	T	75	47		80	54		88	47
8		74	56		93	61		77	48
9	T	73	48		98	54		78	46
10	.05	74	54		78	54		87	48
11		79	56		72	56		68	54
12		90	54		78	48		65	56
13		94	56	.15	81	54		67	54
14		95	58	.02	71	55		73	46
15		96	46		75	53	.02	68	41
16		81	52		72	45	.02	65	37
17	.21	65	51		74	46		69	45
18	.50	66	55		80	53		80	40
19	1.26	59	52		88	51		80	41
20		78	54		87	49		83	42
21		87	53		77	47		84	44
22	.17	80	56		81	51		86	45
23		70	52		86	57		91	49
24		78	55		89	47		76	47
25		76	58		87	46	.01	65	55
26		77	53		90	53	T	71	42
27		73	48		91	50		69	43
28		76	52		90	49		74	49
29		78	48		86	55		84	45
30		76	53		92	53		88	41
31		73	51		96	59			
	Total Precip.	Avg. Temp.	Avg. Temp.	Total Precip.	Avg. Temp.	Avg. Temp.	Total Precip.	Avg. Temp.	Avg. Temp.
	2.23	77.6	52.5	.17	83.9	51.8	.05	78.8	46.8

WEATHER DATA, 1987

Cottage Grove, Oregon

	April			May			June		
Day	Daily Precip. Inches	Temp. °F Max.	Temp. °F Min.	Daily Precip. Inches	Temp. °F Max.	Temp. °F Min.	Daily Precip. Inches	Temp. °F Max.	Temp. °F Min.
1		80	32	.34	58	39		66	34
2		72	32	.15	58	37		77	33
3	.20	62	42	.04	75	48		89	40
4	.08	61	42	T	68	49		84	49
5	.16	57	34		76	41		70	48
6	.04	62	39		86	47		75	51
7	.12	65	47		90	57		81	42
8	.23	64	45		88	50		79	53
9		69	31		89	46		75	45
10	.22	65	37		88	42		76	37
11	.38	53	34		84	41		82	37
12	.10	62	34	.13	74	58		85	42
13		70	33	.02	81	51		87	44
14		75	31		77	53		84	50
15		73	41	.03	71	50	.04	67	48
16		71	39		65	36		65	47
17	.23	63	44		63	35		72	37
18	.13	52	32		62	37		79	36
19	.02	57	29		63	28		83	39
20		68	29		69	30	.04	71	47
21		71	26		74	32	.09	64	46
22		69	36		70	34		74	35
23		71	38		68	34		80	37
24		66	32		64	48		85	40
25		65	32	.05	59	45		94	44
26		83	34	.28	61	43		92	49
27		84	40	T	60	46		89	48
28		83	49	T	69	43		88	48
29		79	38		72	37		95	51
30	.25	77	51	.05	65	47		91	51
31				.29	60	46			
	Total Precip.	**Avg. Temp.**	**Avg. Temp.**	**Total Precip.**	**Avg. Temp.**	**Avg. Temp.**	**Total Precip.**	**Avg. Temp.**	**Avg. Temp.**
	2.16	68.3	36.8	1.38	71.2	42.9	.17	80.0	43.6

WEATHER DATA, 1987

Cottage Grove, Oregon

	July			August			September		
Day	Daily Precip. Inches	Temp. °F Max.	Temp. °F Min.	Daily Precip. Inches	Temp. °F Max.	Temp. °F Min.	Daily Precip. Inches	Temp. °F Max.	Temp. °F Min.
1		88	52		77	41		94	45
2		82	53		84	37		85	42
3		78	48		91	42		76	38
4		72	50		87	46		82	36
5		75	40		84	43		90	38
6		77	44		78	44		87	47
7		79	40		90	42		79	45
8		74	53		97	47		80	47
9		79	42		93	50		84	43
10		78	56		72	41		78	50
11		89	43		77	45	.04	61	50
12		94	48		82	43		61	51
13		95	49	.04	78	53		72	53
14		95	50	.08	72	48	.07	68	39
15		93	41		73	47	.04	65	45
16	.09	70	38		74	39		68	33
17	.03	60	48		77	36		77	31
18	1.84	59	51		85	38		79	32
19	.79	79	50		85	39		83	33
20	T	84	44		82	40		83	34
21	.49	78	50		78	35		85	36
22	.20	71	53		79	38		89	37
23		75	43		87	47		81	44
24		75	53		86	44	T	71	44
25		73	50		88	42	.04	66	50
26		75	51		89	44	.02	68	39
27		74	53		88	43		71	30
28		78	50		86	43		81	32
29		75	53		89	38		86	33
30		72	53		95	45		90	34
31		75	41		103	52			
	Total Precip.	Avg. Temp.	Avg. Temp.	Total Precip.	Avg. Temp.	Avg. Temp.	Total Precip.	Avg. Temp.	Avg. Temp.
	3.44	78.1	48.1	.12	84.1	43.0	.21	78.0	40.4

WEATHER DATA, 1987

Summit, Oregon

	April			May			June		
Day	Daily Precip. Inches	Temp. °F Max.	Temp. °F Min.	Daily Precip. Inches	Temp. °F Max.	Temp. °F Min.	Daily Precip. Inches	Temp. °F Max.	Temp. °F Min.
1		**TEMP.**		.45			.07		
2				.23			.02		
3	.30	**DATA**		.26					
4	.10			.01					
5	.01	**NOT**					.02		
6	.28						.08		
7	.18	**RECORDED**							
8	.22								
9									
10	.02								
11	.69								
12	.51			.30					
13	.01			.03			.01		
14				.02					
15	.02								
16	.04								
17	.24								
18	.63								
19	.13								
20				.02			T		
21							.22		
22							.02		
23									
24				.04					
25				.02					
26				.02					
27				.02					
28	.01			.07					
29	.01			.05					
30	.13			.18					
31				.94					
	Total Precip.	Avg. Temp.	Avg. Temp.	Total Precip.	Avg. Temp.	Avg. Temp.	Total Precip.	Avg. Temp.	Avg. Temp.
	3.53			2.66			.44		

WEATHER DATA, 1987

Summit, Oregon

	July			August			September		
Day	Daily Precip. Inches	Temp. °F Max.	Temp. °F Min.	Daily Precip. Inches	Temp. °F Max.	Temp. °F Min.	Daily Precip. Inches	Temp. °F Max.	Temp. °F Min.
1	.01	**TEMP.**							
2							T		
3		**DATA**					T		
4	T								
5	.19	**NOT**							
6	.14								
7	.02	**RECORDED**							
8	.01						T		
9									
10	.07								
11							.05		
12				T			.04		
13				.11			.01		
14				.12					
15				.02			.14		
16							.04		
17	.30								
18	.68								
19	1.11								
20	.01								
21									
22	.01								
23									
24	T								
25							.03		
26							.08		
27	.01								
28									
29									
30									
31									
	Total Precip.	Avg. Temp.	Avg. Temp.	Total Precip.	Avg. Temp.	Avg. Temp.	Total Precip.	Avg. Temp.	Avg. Temp.
	2.56			.25			.39		