AN ABSTRACT OF THE THESIS OF

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Title: Growth Characteristics and Site Potentials of Perennial Grass Species.

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In this study I assessed the potentials of selected, established perennial grasses to maintain site occupancy in the foothills ecosystem of the Rogue River Valley of southwest Oregon which is currently dominated by a variety of annual plants.

The first evaluation compared growth curves of the perennial grasses and contrasted them to growth patterns of residual annual plants. Periods of growth varied among the perennial grasses studied. Of the perennial grasses, Idaho fescue (Festuca idahoensis), a native, and Berber orchardgrass (Dactylis glomerata var. 'Berber'), introduced, most closely emulated the growth patterns of the majority of the annual plants. Relative to the other perenial grasses tested, they initiated growth earlier, continued some growth through the winter and matured earlier. Once established, they should be able to effectively compete with the resident annuals for resources

and maintain their populations.

To assess the potential for competition for available moisture, the second evaluation considered timing and extent of soil moisture extraction by the perennial grasses and the resident annual community through the periods of active growth. This verified growth analysis results. Idaho fescue and Berber orchardgrass extracted moisture earlier than the other perennial grasses. Perennial grass plots and plots dominated by yellow starthistle (*Centaurea solstitialis*) end of season residual soil moisture levels were similar. Resident annual grasses left considerably more soil moisture. In years with an early summer drought, the earlier growing perennial grasses should be able to satisfy growth requirements and persist.

An assessment was also made of the abilities of several selected established perennial grasses to resist reinvasion by resident annual plants. Earlier growing perennial grasses such as Berber orchardgrass and Idaho fescue suppressed the annuals more effectively than the later growing perennial grasses.

Of the perennial grasses studied, those emulating the growth patterns of the annuals have been the most competitive and have maintained the most vigorous stands.

GROWTH CHARACTERISTICS AND SITE POTENTIALS OF PERENNIAL GRASS SPECIES

by

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TABLE OF CONTENTS

INTRODUCTION 1

LITERATURE REVIEW 5

- Competitive Interactions as a Function of Niche Occupancy 5
- Effect of Summer Drought on Fall Regrowth Response 6
- Vigor - What It Is and How It Is Measured 7
- Growth Analysis 8
- Relative Water Use 9
- Study Method Concepts 11

CHAPTER I - GROWTH PATTERNS AND POTENTIALS OF SELECTED PERENNIAL GRASSES ON THE FOOTHILLS OF THE ROGUE RIVER VALLEY IN SOUTHWEST OREGON 14

- Introduction 14
- Methods 16
  - Study Site 16
  - Plant Materials 17
  - Plot Design 18
  - Sampling 18
  - Experimental Design and Analysis 19
  - Growth Analysis 21
  - Climate and Soil Temperatures 24
- Results and Discussion 29
  - A. Peak Standing Crops 29
  - A.1. All perennial grasses evaluation 29
  - A.2. Selected perennial grasses compared with resident annuals 32
  - A.3. Competition effects 34
  - B. Growth Rates 35
  - B.1. Fall Growth Period 36
  - B.1.a. Perennial grasses analysis (fall growth period) 37
  - B.1.b. Perennial grasses and resident annual plant growth rates compared (fall growth period) 39
  - B.2. Winter Growth Period 41
  - B.2.a. Perennial grasses analyses (winter growth period) 42
  - B.2.b. Competition effects 45
  - B.2.c. Perennial grass and resident annual growth rates compared (winter growth period) 45

Table of Contents, continued

B.3. Early Spring Growth Period 50
B.3.a. Competition effects 50
B.3.b. Perennial grasses analyses (early spring growth period) 51
B.3.c. Perennial grass and resident annual plant growth rates compared (early spring growth period) 55
B.4. Spring and Summer Growth Periods 56
B.4.a. Competition effects during the spring and summer growth periods 59
B.4.b. Spring and Summer Growth Periods 61
B.5. Growth Rates Summary of Results 65
Conclusions 69
Peak Standing Crops 69
Growth Rates 71
Site Adaptability 74

CHAPTER II - TIMING AND EXTENT OF SOIL MOISTURE EXTRACTION BY VEGETATION IN A MEDITERRANEAN/MARITIME REGIME 75

Introduction 75
Materials and Methods 76
Study Site 76
Plot Design 77
Experimental Design and Analysis 78
Neutron Access Tube Installation 79
Sampling 80
Results and Discussion 81
A. Fall Growth Period 81
B. Winter Growth Period 86
C. Early Spring Growth Period 89
D. Spring Growth Period 93
E. Summer Growth Period 97
F. Summary of Points of Interest from Results 102
Conclusions 105

CHAPTER III - EVALUATION OF PERENNIAL GRASSES FOR RESISTANCE TO REINVASION BY ANNUAL WEEDS 110

Introduction 110
Materials and Methods 113
Study Site 113
Plant Materials 114
Plot Design 115
Sampling 116

Table of Contents, continued

Experimental Design and Analysis 117
Results and Discussion 118
Conclusions 130

SUMMARY AND CONCLUSIONS 131

Summary 131
Conclusions 134

BIBLIOGRAPHY 136

APPENDIX

Appendix A - Plot Diagram 140

LIST OF TABLES

Table Page

CHAPTER I

I.1 Perennial grass species included in the study. 17

I.2 Temperature and precipitation summaries for the 1987-88 growing season and from November through May 20 , 1989. 26

I.3 Twenty centimeter soil temperature site comparison. 27

I.4 Twenty centimeter soil temperature comparison of open plots (no vegetation) vs Berber and Palestine orchardgrasses combined. 28

I.5 Site comparisons, 1987 and 1988 peak standing crops. 30

I.6 1987 peak standing crops. Two-way interaction table for species by site. 31

I.7 1988 peak standing crop. Two-way interaction table for species by site. 31

I.8 1988 Peak Standing Crop comparison including only the uncovered subplots. Two-way interaction table by species and site. 33

I.9 Competition effect on 1988 perennial grass peak standing crop. Species included in the analysis were Berber and Palestine orchardgrasses, Intermediate wheatgrass, Tall wheatgrass and Idaho fescue. 34

I.10a Fall 1988 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) whole plot site by species interaction means. 38

List of Tables, continued

Table		Page
I.10b	Fall 1988 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) uncovered subplot site by species interaction means.	40
I.11	Winter (11 December - 12 March) 1987-88 AGR (grams/plant/day) whole plot species main effects.	43
I.12	Winter 1988-89 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) whole plot site by species interaction means.	43
I.13	Winter 1987-88 beginning and ending weights (grams/plant) and RGR (grams/gram initial weight/day) whole plot site by species interaction means.	44
I.14	Winter 1987-88 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) uncovered subplot site by species interaction means.	47
I.15	Winter 1988-89 (17 December - 5 April) AGR (grams/plant/day) uncovered subplot species main effects.	48
I.16	Winter 1988-89 beginning and ending weights (grams/plant) and RGR (grams/gram of initial weight/day) uncovered subplot site by species interaction means.	48
I.17	Early spring growth period competition effects for both AGR (grams/plant/day) and RGR (grams/initial gram of plant/day).	52

List of Tables, continued

Table Page

I.18 Early spring 1988 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) whole plot species main effects. 53

I.19 Early spring 1989 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) whole plot site by species interaction means. 54

I.20 Early spring 1988 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) uncovered subplot site by species interaction means. 57

I.21 Early spring 1989 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) uncovered subplot site by species interaction means. 58

I.22 Competition vs. no competition effects on AGR and RGR during mid and late spring growing periods. 60

I.23 Spring and summer 1988 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) whole plot site by species interaction means. 15 April - 12 May 1988. 62

I.24 Spring and summer 1988 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) whole plot site by species interaction means. 12 May - 24 May 1988. 63

List of Tables, continued

Table		Page
I.25	Spring and summer 1988 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) whole plot site by species interaction means. 24 May - 7 June 1988.	64
I.26	Spring and summer 1988 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) whole plot site by species interaction means. 7 June - 14 June 1988.	66
I.27	Spring and summer 1988 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) whole plot site by species interaction means. 14 June - 28 June 1988.	67

CHAPTER II

II.1 | Preseason (October 16, 1988) site comparison of neutron probe count ratios (measure count/standard count). | 82
II.2 | Preseason (October 16, 1988) species comparison of neutron probe count ratios (measure count/standard count). | 84
II.3 | Fall (December 8, 1988) site by species neutron probe mean count ratios (measure count/standard count) comparison within depth. | 85
II.4 | Winter - early spring transition (April 5, 1989) site by species neutron probe mean count ratios (measure count/standard count) comparison within depth. | 87

List of Tables, continued

Table		Page
II.5	Early spring (5-15 April 1989) species by status [competition (C) vs no competition (NC)] interaction of neutron probe count ratios (measure count/standard count) within depth.	90
II.6	Early spring to spring transition (April 15, 1989) site by species neutron probe mean count ratio (measure count/standard count) comparison within depth.	92
II.7	Spring to summer (May 20, 1988) transition neutron probe count ratio (measure count/standard count) status [competition (C) vs no competition (NC)] comparisons within depth.	94
II.8	Spring to summer transition (May 20, 1988) site by species neutron probe mean count ratios (measure count/standard count) comparison within depth.	96
II.9	End of season (August 24, 1987) site by species neutron probe mean count ratios (measure count/standard count) comparison within depth.	99
II.10	End of season (August 6, 1988) site by species neutron probe mean count ratios (measure count/standard count) comparison within depth.	101

CHAPTER III

Table		Page
III.1	Perennial grass species included in the study.	115
III.2	May 1988 mean percent foliar cover (percent cover) and dry matter biomass of resident annual plants per perennial grass plant as measured within a 25cm X 25cm quadrat.	119

List of Tables, continued

Table		Page
III.3	June 1988 mean percent foliar cover (percent cover) and dry matter biomass of resident annual plants per perennial grass plant as measured within a 25cm X 25cm quadrat.	120
III.4	December 1988 species main effects mean percent foliar cover (percent cover) and dry matter biomass of resident annuals per perennial grass plant as measured with a 25cm X 25cm quadrat.	123
III.5	January 1989 site by species interaction effects mean percent foliar cover (percent cover) and dry matter biomass of resident annuals per perennial grass plant as measured with a 25cm X 25cm quadrat.	124
III.6	March 1989 species main effects mean percent foliar cover (percent cover) and dry matter biomass of resident annuals per perennial grass plant as measured with a 25cm X 25cm quadrat.	125
III.7	March 1989 site main effects mean percent foliar cover (percent cover) and dry matter biomass of resident annuals per perennial grass plant as measured with a 25cm X 25cm quadrat.	127
III.8	April 5, 1989 species main effects mean percent foliar cover (percent cover) and dry matter biomass of resident annuals per perennial grass plant as measured with a 25cm X 25cm quadrat.	128
III.9	April 15, 1989 site by species interaction effects mean percent foliar cover (percent cover) and dry matter biomass of resident annuals per perennial grass plant as measured with a 25cm X 25cm quadrat.	129

GROWTH CHARACTERISTICS AND SITE POTENTIALS OF PERENNIAL GRASS SPECIES

INTRODUCTION

Foothill pastures and rangelands of the Rogue River Valley in southwestern Oregon are dominated by introduced annual weeds. Historically these foothills were used as winter feeding areas for livestock. Severe overstocking over a period of many years resulted in a species composition dominated by the annual grasses medusahead (*Taeniatherum asperum*), dogtail (*Cynosurus echinatus*), bulbous bluegrass (*Poa bulbosa*), and ripgut brome (*Bromus rigidus*); and by assorted annual forbs including yellow starthistle (*Centaurea solstitialis*). Today these foothills pastures are used primarily as spring, and to a lesser degree, fall grazing areas during the transition period between winter on irrigated pasture in the valley and summer in the high country. For a relatively brief period in the spring, the annual grasses provide good forage value. However, in most years the time period in which they have good forage value is quite short. Yellow starthistle which produces most of its growth in the late spring and early summer is able to capitalize on the moisture not utilized by the annual grasses and dominates these sites through the late spring and summer. This species is toxic to horses which eat the weed when it is very young, before it has developed its yellow flower with long stiff spines. As the plant matures, the spiny seedhead becomes a nuisance.

From both forage resource and conservation perspectives, a perennial grass dominant would be much preferable to the resident annual mix. Perennial grasses would be expected to produce a greater amount of available forage for livestock over a longer period of time in the important spring - early summer grazing period. They should also provide a more stable forage base than the extremely variable production exhibited by resident annuals. Perennial grasses would facilitate planning of grazing management. Through a more extensive and deeper rooting system, most perennials should be better than annuals in improving soil structure and in reducing erosion potential. A period of growth extending into summer should result in greater soil moisture depletion and suppression of yellow starthistle.

Pastures and rangelands of the interior valleys of California are presently managed as annual grasslands. The foothills areas of the Willamette Valley of Oregon can be managed to support perennial grass species. The hypothesis leading to the development of this study was that the foothills areas of the Rogue River Valley lie in a transition zone between these two regions. As a general objective, this study was designed to determine whether or not the ecosystem encompassing the interior valley foothills of the Rogue River Valley would support a perennial grass dominant, or if it is indeed an annual grassland and should be managed as such.

If perennial grasses did at one time dominate these sites, they have not been able to regain entry other than in limited favorable microsites. The absence of perennial species may be the result of competition by annual weeds following suppression by overgrazing or it may be a function of endemic heavy clay soils and climatic conditions largely precluding the establishment of communities of desirable perennial grasses beyond favorable microsites. The limited distribution of native perennial grasses and their virtual exclusion from open sites effectively eliminate grazing management alone as a method of improvement within a reasonable period of time. If significant improvement is to be accomplished, a reseeding effort will be required. Before ranchers and other land managers expend additional time and resources in an attempt to find the perennial grass alternatives to be used in a reseeding effort, the potential for establishing and maintaining a perennial grass component should be clarified. The competitive relationships between the perennials thought to have potential and the indigenous annuals must be understood if more than trial and error attempts at range improvements are to be made.

In order to meet the objective of this study, the following evaluations were performed:

1. Growth curves of selected perennial grasses were compared among each other and contrasted to annual plant growth patterns in an attempt to identify growth patterns conducive to maintaining site occupancy.
2. Timing and extent of soil moisture extraction by selected perennial grasses and the resident annual community through the periods of active growth were evaluated to identify potential advantages and disadvantages accruing to each with respect to competition for available soil moisture.
3. An assessment of the abilities of several selected perennial grasses to resist reinvasion by resident annual plants once the perennials had had a reasonable chance to become established was made to identify those most likely to maintain a stand over a period of time.

LITERATURE REVIEW

Competitive Interactions as a Funciton of Niche Occupancy

Several studies have concluded that in competition among seedlings, the period of active growth is a major determinant of dominance (Harris 1967, Harris and Wilson 1970, Ross and Harper 1972, Wilson, et.al. 1966). Generally, individual plants able to germinate and commence growth earliest are those with the most significant competitive advantage. In competition among winter growing perennials and annuals, the ability to continue growth through the cold period contributed to the competitive advantage of cheatgrass (_Bromus tectorum_) and medusahead (_Taeniatherum asperum_) over bluebunch wheatgrass (_Agropyron spicatum_) seedlings (Harris 1967, Harris and Wilson 1970). In contrast, the root tips of crested wheatgrass (_A. desertorum_) seedlings were able to penetrate the soil almost as rapidly as the two annuals and remain in favorable soil moisture (Harris and Wilson 1970).

Under conditions to which they are adapted, established mature perennial grasses have a natural competitive advantage over annual grasses (Harris 1967, Harris and Wilson 1970). Prior root development facilitates maintenance of contact with available soil moisture (Harris 1977). It is not necessary for perennial grasses to begin from seed following each dormant period. However, once mature plants are removed, and re-establishment from seed is required, perennials are at a disadvantage.

Connell and Slatyer (1977) have proposed and have tended to support the "inhibition" model of secondary succession. The "inhibition" model states that all species resist invasion by competitors. The first occupants preempt the space and continue to exclude or inhibit late colonists until the former die or are damaged.

Effect of Summer Drought on Fall Regrowth Response

Jackson and Roy (1986) have suggested that different rainfall patterns between the mediterranean type climates of southern France and California may partially explain the contrasting roles of perennial grasses in the two regions. They felt that the earlier and longer summer drought in California may be a factor in preventing the successional replacement of non-native annuals by native perennials. In a comparative study of their biogeography in several regions of the Mediterranean Basin, Jackson (1985) described the key factors that appear to result in a high abundance of annual grasses: a ruderal environment, high winter rainfall, and relatively long summer drought. These environmental requirements were met when annual grasses were introduced into the overgrazed California grasslands.

Results of the Jackson and Roy (1986) study suggested that the earlier and often very sudden drought in California does not affect the annual grasses but reduces the production of the perennial grasses in their autumn growth. The perennial grasses included in the study were *Dactylis glomerata* and *Bromus erectus* from French populations and *Stipa pulchra* and *Poa scabrella* from California populations. An imposed April drought treatment, contrasted to precipitation into June, reduced the numbers of leaves and tillers and total plant biomass in the perennial grasses, and autumn regrowth was lower for the droughted plants. The annuals in the study were not affected by the drought. Since the study was conducted on seedlings and over only a one year period, the authors could not assess the abilities of the perennial grasses to maintain site occupancy. However, the implications were that establishment would be less likely under the extended drought conditions of California and that the perennial grasses would not generally have the opportunity to develop the vigor necessary to maintain niche occupancy.

Vigor -
What It Is and How It Is Measured

Plant vigor is synonymous with the status or health of the plant. It denotes the relative appearance, vitality, rate of growth and herbage production of a plant. A vigorous plant has reserve vitality and is free from defects and disease. For maximum vigor, it requires a favorable environment (Cook and Stubbendieck 1986). The criteria for evaluating grass vigor are a combination of plant height, leaf length and herbage yield. All the factors that affect plant vigor are integrated in herbage production. Therefore, herbage yield is undoubtedly a more accurate measure of plant vigor than any single vegetation characteristic. Other characteristics that help describe relative vigor would include timing and rate of growth.

Growth Analysis

> "All plants as they proceed through their life cycles, are capable of change in size and form if exposed to suitable contitions. The processes that result in physiological and morphological changes as a plant ages are strongly interlinked, and the term 'growth' is used for any or all of them. Growth in the above context means the irreversible increase in plant size, which is often accompanied by changes in form and occasionally by changes in individual numbers. The fact that growth is a universal phenomenon of all plant life is certain. It is the amount of growth (however measured) resulting from influences of various biotic or abiotic factors that influences competitive interactions among plants. A better understanding of resource limitation and its consequences surely could result from the analysis of growth parameters of individual plants involved in a competitive relationship" (Radosevich and Holt 1984).

Growth analysis has been extensively used in quantitative studies of plant growth because of the fundamental nature of growth-analytical quantities: they describe the situation de facto, integrated both throughout the plant and across intervals of time (Hunt 1982). Absolute growth rate (AGR) is a simple measure of the rate of increase in weight of a plant per unit time:

$$AGR = (W_2 - W_1)/(T_2 - T_1).$$

Mean relative growth rate (RGR) is the increase in plant material per unit of material per unit of time. RGR adjusts for initial plant size and provides a comparison of the plants' relative performances:

$$RGR = (\ln W_2 - \ln W_1)/(t_2 - t_1)$$

where W and t are weight and time, respectively. RGR is derived from an equation first proposed by Blackman (1919) for relative growth rate (R).

$$R = (1/W)*(dW/dT)$$

where W and T are weight and time, respectively (Evans 1972, Hunt 1982, Radosevich and Holt 1984).

Relative Water Use

The success of plants in the Mediterranean climate type is dependent on the ability to survive two periods and types of stress: winter cold and summer drought (Miller 1981). Successful plants would either access soil moisture from a different level than others or would have to be successful competitors for available soil moisture during the spring and early summer when temperatures are optimum for growth but soil moisture is generally becoming increasingly limited.

Eissenstat (1986) and Eissenstat and Caldwell (1988) found that the success of indicator plants in the Great Basin could be related to the ability of monospecific stands of test species to extract soil moisture under similar conditions. They found species differences in the rate of water extraction and in the ability to maintain differences through the sampling period. In a related study, Thorgeirsson (1985) monitored timing, rate and depth of soil moisture extraction in monocultures of _Agropyron desertorum_ and _A_. _spicatum_ and in grass-shrub mixtures of each with _Artemisia tridentata_. Davis and Mooney (1986) examined the possibility of root stratification promoting a sharing of soil moisture resources by comparing seasonal water use patterns in a mixed stand of chaparral dominated by different shrubs. Cable (1969) found differences in water use among species, among seasons and at various depths. He was able to describe relative competitive abilities among the species on the basis of timing of soil moisture utilization and depth from which moisture was being extracted at any given time.

Study Method Concepts

Numerous studies have been conducted to determine competitive interactions between perennial and annual grass seedlings (Harris 1967, 1977, Harris and Wilson 1970, Jackson and Roy 1986, Rummell 1946, Young, et.al. 1968 a,b). However, field studies that bypass the seedling establishment phase to determine species potential to maintain niche occupancy have not been tried under conditions similar to those in the study area. Studies by population biologists would most closely approximate this approach. An approach similar to that which I used was used by Cable (1969) in Arizona. The study was designed to describe competitive interactions among perennial grasses, annual grasses and burroweed (*Aplopappus tenuisectus*) by selectively weeding plots to obtain stands of each alone and in all possible combinations. He was able to describe periods of growth, amounts of growth and soil moisture depletion responses among the species studied to determine competitive interactions and niche occupancy. Among his results he noted that perennial grasses compete strongly with summer annual grasses in wet years because they grow at the same time, and the perennial grass root systems are already in place and occupy the same soil layer used by annual grasses which must start from seed. Cable studied warm season grasses in a summer growth period, but the approach should also be useful for cool season species in a

Mediterranean or Maritime climate.

Plant materials field plantings have been conducted in the study area over the past several years with the goal of identifying grass and forb species for use as replacements of the annual weeds. Species such as tall wheatgrass (Agropyron elongatum) and sheep fescue (Festuca ovina) have shown some potential over a range of sites and soil types. According to the Jackson County SCS office and Extension Service, ranchers in the area have not been enamored of either species because of the comparatively low palatability of the wheatgrass and low production of the fescue. In a tall wheatgrass field trial proposal dated 12/85, ranchers were described as desiring "better" grasses which has caused them to try many other species, not as well adapted, only to meet with failure and conclude that their soils are good only for growing winter annual weeds. Many have apparently concluded that they must be satisfied with and manage for these conditions.

Plant materials screening trials in central Tunisia, North Africa have indicated a potential for the production of Berber and Palestine orchardgrasses (Dactylis glomerata var. 'Berber' and 'Palestine') and of Intermediate wheatgrass (Agropyron intermedium) under climatic conditions similar to but more extreme than those of the study area in southwest Oregon (Borman 1986, Hess 1984, Johnson 1986). The soils were generally more depleted and conditions in general were more difficult for perennial grass production in central Tunisia relative to southwest Oregon.

CHAPTER I

GROWTH PATTERNS AND POTENTIALS OF SELECTED PERENNIAL GRASSES ON THE FOOTHILLS OF THE ROGUE RIVER VALLEY IN SOUTHWEST OREGON

Introduction

The foothills of the Rogue River Valley in southwest Oregon are currently dominated by a variety of undesirable annual plant species. From both forage resource and conservation perspectives, a perennial grass dominant would be preferable to the resident annual mix. Perennial grasses should produce a greater amount of available forage for livestock over a longer period of time in the important spring through early summer grazing period. They should also provide a more stable forage base than the typically extremely variable production exhibited by annuals from one year to the next in a Mediterranean/Maritime climate. A more stable forage base would facilitate planning of grazing management. In addition, through a more extensive and deeper rooting system, most perennials should be better than annuals in improving soil structure and in reducing erosion potential.

Numerous studies have been conducted to determine competitive interactions between perennial and annual grass seedlings (Harris 1967, 1977, Harris and Wilson 1970, Jackson and Roy 1986, Rummell 1946, Young, et.al. 1968 a,b). However, field studies that bypass the seedling establishment phase to determine species' potentials to maintain niche occupancy have not been conducted under conditions similar to those in the study area. Established mature perennial grasses have a natural competitive advantage over annual grasses (Harris 1967 and Harris and Wilson 1970) because of prior root development which maintains contact with available soil moisture (Harris 1977). However, Jackson and Roy (1986) have suggested that the ability of perennial grasses to maintain site occupancy in a Mediterranean climate may be a function of rainfall patterns. They suggested that the early and often very sudden drought in California does not affect the annual grasses but reduces the production of the perennials in their autumn growth. Reduced autumn regrowth would compound the effect of lower production at quiescence and result in a plant with less vigor and, thus, lower the competitive advantage an established perennial is expected to have over the annual plants.

In a general sense, this study was designed to determine whether or not the ecosystem encompassing the interior valley foothills of the Rogue River Valley is capable of supporting a perennial grass dominant, or if it is indeed an annual grassland and should be managed as such. Growth curves of selected perennial grasses were compared among each other and contrasted to annual plant growth patterns in an attempt to identify growth patterns conducive to maintaining site occupancy under conditions similar to those described by Jackson and Roy (1986) for California. Since competitive interference from resident annuals is thought to inhibit perennial grasses in this system, growth curves and peak standing crops of perennial grasses were compared with and without competition from the annuals.

Methods

Study Site

The study was conducted at two foothills sites in Jackson County in southwest Oregon. Site 1 (mid slope) is located 3 km east of Phoenix on the Ferns ranch, and Site 2 (toe slope) is located about 5 km northeast of Ashland on the Dauenhauer ranch. Soils at the two sites are Darrow silty clay loam and Carney clay, respectively. The Darrow series consists of moderately well drained soils formed in weathered siltstone or shale bedrock. Permeability is slow. The effective rooting depth is commonly 75 to 100 cm. Shrink-swell potential is moderate in the surface 30 cm and high below 30 cm. The Carney series consists of moderately deep, moderately well drained soils on fans and hillslopes. These soils formed from alluvium and colluvium weathered from Tuffs and Breccias. Typically, these soils are dark brown clay throughout. Permeability is slow.

Shrink-swell capacity is severe throughout. Sites 1 and 2 have west and southwest aspects, respectively; and slopes are 20-35% (mid slope) and 5-20% (toe slope), respectively. The area is characterized by a Mediterranean/Maritime climate pattern with cool wet winters and hot dry summers. Annual precipitation averages 500 - 600 mm at both sites, but distribution and quantity vary considerably from year to year. On average, approximately 82% of the precipitation falls between October 1 and April 30, 4.8% in May, 2.3% in June and 0.7% in July. The average January temperature is 3.3°C and the average July temperature is 21.1°C. Extreme temperatures range from -20°C to 41°C.

Plant Materials

Eleven species or varieties of species (Table I.1) of perennial grass were evaluated. Three of the species were natives growing in association with oak (*Quercus garryana*) on sites similar to the study sites. The others were introduced species.

Table I.1. Perennial grass species included in the study.

Agropyron elongatum	Tall wheatgrass
A. intermedium	Intermediate wheatgrass
A. varnense	Rush wheatgrass
Dactylis glomerata	
varieties 'Berber'	Berber orchardgrass
'Paiute'	Paiute orchardgrass
'Palestine'	Palestine orchardgrass
Danthonia californica	California oatgrass (native)
Festuca arundinacea	Tall fescue
Festuca idahoensis	Idaho fescue (native)
Koeleria cristata	Junegrass (native)
Lolium perenne	Perennial ryegrass

Plot Design

All plants were transplanted into plots during the fall and winter of 1986-87 and allowed to establish in the absence of competition during the 1986-87 growing season. Supression of competition was accomplished by transplanting into plots covered with black vispore. The vispore, a black plastic material, had 400 holes per square inch to allow water and air passage. Following establishment during the first growing season, the plots were split by removing the vispore from half of each plot. The resident annuals were thus allowed to provide competition for the perennials on half of each plot while the perennials remained competition free on the other half. Plants growing without competitive interference provided an assessment of growth potentials on the sites.

Sampling

To avoid destructive harvesting within the plots, the sampling procedure used was the weight estimate technique (Pechanec and Pickford 1937). Fifteen individual plants per subplot were sampled to obtain a mean for the subplot. Plants on the perimeter of the plots and additional plants transplanted around the perimeter of each site served as calibration plants. Sampling for establishment year peak standing crops was conducted during the summer of 1987. During the 1987-88 and 1988-89 growing seasons, sampling was initiated following sufficient precipitation to initiate regrowth. The 1987-88 growing season began in December and sampling was conducted once a month through March to evaluate winter growth then biweekly for the duration of the growing season and terminated in the summer after maturity. The 1988-89 growing season began in November. Sampling was conducted once a month through mid-March to evaluate fall and winter growth then biweekly through mid-April to evaluate early spring growth. Sampling was terminated on April 15, 1989.

Experimental Design and Analysis

The study was replicated at two sites within the Rogue River Valley. The plot layout within each site consisted of three blocks each of which contained randomly assigned perennial grass species and control subplots. Each perennial grass subplot was further divided into randomly assigned with and without competition sub-subplots. The data were then analyzed using a split-split-plot ANOVA model:

Source	d.f.
Site	(a-1)
Block (Site)	(b-1)a
Species	(c-1)
Site * Species	(a-1)(c-1)
Species * Block (Site)	(c-1)(b-1)(a)
Competition	(d-1)
Competition * Site	(d-1)(a-1)
Competition * Species	(d-1)(c-1)
Competition * Site * Species	(d-1)(a-1)(c-1)
Competition * Block (Site) + Competition * Species * Block (Site)	(d-1)(b-1)(a) + (d-1)(c-1)(b-1)(a)

Each site was analyzed as a whole plot, each species as a subplot within site, and competition as a sub-subplot within species, within site. Since Block 1 at Site 1 was not necessarily the same as Block 1 at Site 2, block was nested within site (i.e. Block (Site)) for the analysis rather than treated separately. Block (Site) (i.e. block nested within site) served as the error term for Site. Species * Block (Site) served as the error term for Species and Site * Species. The last term of the model served as the expermimental error term for the Competition and Competition interactions.

Since the vispore was used to suppress resident annual weeds, it was not possible to compare resident annual weeds subplots to perennial grasses subplots (with and without vispore cover) because the resident annual weeds subplots did not have a vispore covered sub-subplot. Therefore, when comparing resident annual weeds to perennial grasses, the vispore covered sub-subplots of the perennial grasses had to be ignored and the analysis made as if it did not exist. In order to assess the perennial grasses with respect to resident annual weed production, the following model was used:

Source	d.f.
Site	(a-1)
Block (Site)	(b-1)a
Species	(c-1)
Site * Species	(a-1)(c-1)
Species * Block (Site)	(c-1)(b-1)(a)

Again, block was nested within site and Block (Site) served as the error term for Site. Species * Block (Site) served as the error term for Species and for Site * Species interaction effects. Since the covered (no competition) sub-subplots were not included, this analysis was a split-plot ANOVA.

To account for auto-correlation of dates of sampling, multivariate ANOVA was first conducted to provide a conservative screen for significant differences. Univariate analysis followed when differences were detected. An F-protected LSD was used following a significant F-ratio of at least the $P \leq 0.10$ level.

Growth Analysis

Plant growth analysis was determined to be the appropriate methodology for comparing the growth patterns and potentials of the perennial grasses included in this study because of the fundamental nature of growth-analytical quantities: they describe the situation de facto, integrated both throughout the plant and across intervals of time (Hunt 1982). Both absolute and mean relative growth rates were compared. Absolute growth rate (AGR) is a simple measure of the rate of increase in weight of a plant per unit time.

$$AGR = (W_2 - W_1)/(T_2 - T_1)$$

Mean relative growth rate (RGR) is the increase in plant material per initial unit of material per unit of time.

RGR adjusts for initial plant size and provides a comparison of the plants' relative performances. As used in this study, RGR is equivalent to the mean rate of gain in grams of added growth per gram of initial plant weight per day. Initial plant weight was the weight of the plant at the beginning of a sampling period (e.g. at the beginning of the fall growth period, of the winter growth period, etc.).

$$RGR = (\ln W_2 - \ln W_1)/(t_2 - t_1)$$

where W and t are weight and time, respectively. RGR is derived from an equation first proposed by Blackman (1919) for relative growth rate (R).

$$R = (1/W)*(dW/dT)$$

where W and T are weight and time, respectively (Evans 1972, Hunt 1982, Radosevich and Holt 1984).

Growth rate comparisons were made within seven different periods during the 1987-88 growing season. Growth initiating rain did not occur until December 1987 which precluded a fall growth period. Period 1 corresponded to the winter growth phase based on temperatures and growth patterns. It included December 1987 through early March 1988. The second period corresponded to the early spring growth phase based on temperatures. Period 2 included the latter two-thirds of March through mid-April. Period 3, mid-April to mid-May, represented spring growth. By the end of period 3, most plants had initiated reproductive culm elongation. Periods four through seven were on a sampling period basis because of fluctuations which resulted from differing times of maturity among the species and increasing moisture limitation which was relieved briefly by an early June rain. Periods four through seven were 12 - 24 May, 24 May - 7 June, 7 - 14 June and 14 - 28 June, respectively. Rain through the first week in June was responsible for the change in sampling schedule at that time.

Growth rate comparisons were made in the 1988-89 growing season through mid-April. Based on precipitation patterns, temperatures and growth patterns, the 1988-89 growing season was divided into three periods. Growth initiating rain arrived in November 1988 and provided the only fall growth period within the two years of this study. Period 1, the fall growth period, was from mid-November to mid-December 1988. Period 2, the winter growth period, was from mid-December 1988 through the April 5, 1989 data collection. Period 3, the early spring period, was from April 5 through April 15, 1989. By April 15, most of the Idaho fescue plants at both sites were in the boot stage of phenological development. Many Berber orchardgrass plants were in boot at Site 1 but not yet at Site 2. Very few Palestine orchardgrass plants at Site 1 and none at Site 2 were in boot. The wheatgrasses had only just gotten a good start during the early spring period and were all still vegetative.

Beginning with the 1987-88 growing season, intensive sampling was restricted to Idaho fescue, Berber and Palestine orchardgrasses, Intermediate wheatgrass and Tall wheatgrass. Resident annuals were sampled as grasses and forbs.

Climate and Soil Temperatures

Temperature was continuously recorded with a hygrothermograph at each site. Precipitation accumulation between sampling periods was measured at each site. Soil temperatures were recorded at depths of 2 cm and 20 cm in the Open plots (no vegetation) and in the Berber and Palestine orchargrass plots in both vispore covered and uncovered subplots. Thermocouples constructed of number 24 gauge copper-constantan wire were placed in the plots in January 1988. Soil temperature measurements were made with a Wescor HR-33T dew point microvoltmeter.

Daily temperature fluctuations were remarkably similar for the two sites. Hygrothermograph tracings were virtual replicas most of the time. Average temperatures at Site 1 relative to Site 2 were slightly lower in the winter and slightly higher in the summer (Table I.2). Distribution of precipitation was essentially the same at the two sites.

Twenty centimeter soil temperatures were quite different at the two sites. Twenty centimeter temperatures were consistently a degree or more warmer at Site 1 than at

Site 2, winter and summer (Table I.3). Differences in slope and aspect were probably the major contributors to the differences. Through periods of active growth, the Open plot (no vegetation) 20 centimeter soil temperatures were warmer than those in the orchardgrass plots (Table I.4). Since the twenty cemtimeter soil temperatures in the two orchardgrass plots were not statistically different, they were pooled for comparison with the Open plots. Vispore may have had a moderating effect on soil temperatures through the winter months. Temperature differences between vispore covered and uncovered subplots were generally not different during the spring or summer periods. Exceptions were during April 1989 when vispore covered subplots were cooler at 20 cm depth.

Table I.2. Temperature and precipitation summaries for the 1987-88 growing season and from November through May 20, 1989.

Month	Site 1 (mid slope)			Site 2 (toe slope)		
	°C mean max.	°C mean min.	pptn. (cm)	°C mean max.	°C mean min.	pptn. (cm)
December 87	7.1	1.2	7.32	8.3	2.1	7.39
January 88	8.1	1.2	3.30	9.4	2.3	3.00
February	14.6	2.2	1.22	16.0	3.0	1.17
March	15.8	2.7	2.49	17.1	3.2	2.82
April	18.1	6.5	3.07	19.4	7.1	2.36
May	21.1	7.5	5.54	22.2	8.0	5.00
June	26.4	10.9	5.82	27.2	15.4	7.04
July	36.9	16.2	0.00	36.3	16.5	0.00
Precipitation total for the 1987-88 growing year			28.75			28.78
November 88	8.3	2.3	4.72	9.7	2.2	5.61
December	5.1	-1.6	7.11	7.9	-0.5	5.36
January 89	4.7	-2.5	8.15	6.5	-1.8	9.35
February	6.5	-2.6	4.55	7.2	-2.4	3.45
March	10.7	2.2	10.87	10.3	1.6	10.74
April	18.3	5.6	5.51	17.5	4.1	6.43
May 20	19.4	6.9	2.87	19.8	5.3	1.96
Precipitation total for the 1988-89 growing year through May 20			43.78			42.90

Table I.3. Twenty centimeter soil temperature site comparison. Different letters within a row indicate significant differences ($P < 0.10$) within a date.

Year	Date	Site 1	Site 2
1988	Jan 9	6.5 a	5.5 b
	Jan 24	5.4 a	4.9 b
	Feb 20	8.5 a	7.4 b
	Mar 14	10.2 a	8.6 b
	Apr 13	16.3 a	14.8 b
	Apr 26	14.4 a	14.0 b
	May 11	16.0 a	13.6 b
	May 24	18.7 a	17.6 b
	Jun 7	15.5 a	14.3 b
	Jun 17	22.6 a	20.0 b
	Jun 27	25.2 a	21.4 b
	Jul 15	26.6 a	23.3 b
	Jul 28	30.5 a	26.2 b
	Oct 16	21.0 a	18.2 b
	Nov 17	10.7 a	8.9 b
	Dec 8	9.1 a	9.0 a
	Dec 18	6.7 a	6.4 b
1989	Jan 19	6.3 a	5.0 b
	Mar 1	8.2 a	7.2 b
	Mar 16	9.9 a	8.3 b
	Apr 5	12.2 b	12.5 a*
	Apr 16	17.8 a	15.8 b

* For this sampling period, measurements were taken on two days. Order of sampling made a difference this time because a major warming trend had just begun. Site 1 was sampled on 5 April and site 2 on 6 April. If they had been sampled on the same day, it is likely that the trend would not have been interupted.

Table I.4. Twenty centimeter soil temperature comparison of open plots (no vegetation) vs Berber and Palestine orchardgrasses combined. Different letters within a row indicate significant differences ($P < 0.10$) within a date.

Year	Date	Open	Orchardgrasses
1988	Jan 9	6.0 a	6.0 a
	Jan 24	5.2 a	5.2 a
	Feb 20	8.1 a	7.9 b
	Mar 14	9.8 a	9.2 b
	Apr 13	16.0 a	15.3 b
	Apr 26	14.8 a	14.0 b
	May 11	15.5 a	14.4 b
	May 24	19.0 a	17.7 b
	Jun 7	15.5 a	14.7 b
	Jun 17	22.5 a	20.8 b
	Jun 27	24.4 a	22.8 b
	Jul 15	26.0 a	24.5 b
	Jul 28	29.3 a	28.0 b
	Oct 16	20.3 a	19.6 b
	Nov 17	9.7 a	9.8 a
	Dec 8	9.1 a	9.1 a
	Dec 18	6.7 a	6.5 a
1989	Jan 19	5.8 a	5.7 b
	Mar 1	7.9 a	7.6 b
	Mar 16	9.2 a	9.0 b
	Apr 5	12.6 a	12.2 a*
	Apr 16	17.6 a	16.5 b

* Open plot temperatures were significantly greater than Berber orchardgrass plots ($P < 0.10$) but not different than Palestine orchardgrass plots ($P > 0.10$). Palestine and Berber orchardgrass plots were not different ($P > 0.10$).

Results and Discussion

A. Peak Standing Crops

Peak standing crop was significantly greater ($P < 0.05$) in both 1987 and 1988 at Site 2 compared to Site 1 (Table I.5).

A.1. All perennial grasses evaluation

Site by species interactions were significant ($P < 0.01$) in both 1987 and 1988. Two-way tables of means (site by species) are presented for both 1987 (Table I.6) and 1988 (Table I.7). During 1987 Tall wheatgrass, Rush wheatgrass and Palestine orchardgrass produced considerably more dry matter at Site 2 than at Site 1. Perennial ryegrass and Junegrass produced less at Site 2 than at Site 1. 1987 was characterized by a dry spring but received 8.0 cm of rain in early July.

1988 was also characterized by a dry spring. However, it was not as severe as in 1987 and precipitation distribution was better. Rain in early June provided additional moisture for a short period. During 1988 Idaho fescue, the three orchardgrasses, Intermediate wheatgrass, Rush wheatgrass, and perennial ryegrass produced considerably more dry matter at Site 2 than at Site 1 while Tall wheatgrass, Tall fescue and Junegrass produced less.

Table I.5. Site comparisons, 1987 and 1988 peak standing crops. All perennial grasses except California oatgrass are included in the means. Since site by competition interaction was not significant in 1988, the means include both vispore covered and uncovered subplots. Vispore covered the entire plot through the 1987 season. Means represent grams dry matter biomass per plant. Grams per plant * 160 = kg/ha. Means within year are significantly different ($P < 0.05$) for both years.

Site	1987	1988
1 (mid slope)	5.66	18.75
2 (toe slope)	8.31	26.43

Table I.6. 1987 peak standing crops. Two-way interaction table for species by site. Numbers are mean grams dry matter biomass per plant (grams per plant * 160 = kg/ha).

	Site	
Species	1 (mid slope)	2 (toe slope)
Intermediate wheatgrass	8.75 a *	8.37 cd
Tall wheatgrass	6.02 abcd	17.64 a
Rush wheatgrass	5.10 bcde	11.27 b
Berber orchardgrass	5.11 bcde	7.23 d
Palestine orchardgrass	6.81 abc	10.38 bc
Paiute orchardgrass	5.01 bcde	7.87 cd
Idaho fescue	7.52 ab	8.88 bcd
Tall fescue	5.68 bcd	7.67 cd
Junegrass	3.85 de	2.16 e
Perennial ryegrass **	2.75 e	1.62 e

* Within site, mean values with the same letter are not significantly different at $P < 0.10$.

** Standard error of the difference for two means within a site is 1.704, 36 d.f.

Table I.7. 1988 peak standing crop. Two-way interaction table for species by site. Since the species by competition interaction was not significantly different ($P > 0.20$) both vispore covered and uncovered subplots have been combined in the analysis. Numbers are mean grams dry matter biomass per plant (grams per plant * 160 = kg/ha).

	Site	
Species	1 (mid slope)	2 (toe slope)
Intermediate wheatgrass	24.76 a *	35.72 ab
Tall wheatgrass	21.57 abc	18.72 ef
Rush wheatgrass	22.08 ab	31.78 b
Berber orchardgrass	22.07 ab	32.37 bc
Palestine orchardgrass	21.33 abc	28.76 bcd
Paiute orchardgrass	14.19 cd	25.79 cde
Idaho fescue	22.01 ab	41.40 a
Tall fescue	14.85 bcd	13.92 f
Junegrass	14.74 bcd	14.36 f
Perennial ryegrass **	9.90 d	21.48 d

* Within site, mean values with the same letter are not significantly different at $P < 0.10$.

** Standard error of the difference for two means within a site is 4.361, 36 d.f.

A.2. Selected perennial grasses compared with resident annuals

Peak standing crops of the five intensively sampled perennial grasses and the resident annuals in the uncovered subplots were compared for 1988 (Table I.8). Again the site by species interaction was significant ($P < 0.05$). Of the five intensively sampled species, Tall wheatgrass was the only species producing less at Site 2 than at Site 1. Tall wheatgrass was the latest maturing of the perennial grasses included in the study. It is likely that as Tall wheatgrass was approaching maturity moisture was the limiting factor with respect to its production at Site 2.

Since slope, aspect and soils were all different, and therefore confounded, between the two sites, an explanation of the superiority of peak standing crop at Site 2 vs Site 1 in 1987 and 1988 must be conjectural. Because of the difference in slope and aspect, Site 2 received direct sunlight one to two hours earlier in the morning when temperatures were moderate. In 1987, while perennial grass plants were still becoming established, they were slow to mature, and were able to take advantage of the early July rain. Because of the light and temperature advantages described above, plants at Site 2 were able to take greater advantage of the additional late moisture. In 1988, the early June rains replenished depleted soil moisture. At Site 2, the plants were further advanced phenologically and

Table I.8. 1988 Peak Standing Crop comparison including only the uncovered subplots. Two-way interaction table by species and site. Numbers are mean grams dry matter biomass per plant for the grasses and mean grams dry matter biomass per 625 sq.cm. quadrat for the weeds (grams per plant or per quadrat * 160 = kg/ha).

	Site	
Species	1 (mid slope)	2 (toe slope)
Idaho fescue	20.88 a *	39.65 a
Berber orchardgrass	18.16 a	28.07 b
Palestine orchardgrass	16.43 a	27.26 b
Intermediate wheatgrass	23.48 a	32.76 ab
Tall wheatgrass	23.39 a	16.17 c
Resident annuals	17.66 a	30.53 b

* standard error of the difference for two means within a site is 4.5189, 20 d.f. Within a site, means with the same letter are not significantly different at $P < 0.10$.

were able to capitalize on the additional moisture to complete maturation. Slope and aspect effects on the duration of sunlight per day, especially with more moderate morning temperatures, may have contributed to the higher productivity evident at Site 2 during this study. The late season, July 1987 and June 1988, precipitation probably accentuated the difference between the two sites in those two years.

A.3. Competition effects

In 1988 the difference in peak standing crops of perennial grasses with and without competition from resident annuals was significant ($P < 0.01$) (Table I.9). Protection from competition by vispore was beneficial to overall production at both sites.

Table I.9. Competition effect on 1988 perennial grass peak standing crop. Species included in the analysis were Berber and Palestine orchardgrasses, Intermediate wheatgrass, Tall wheatgrass and Idaho fescue. Means are grams dry matter biomass per plant (grams per plant * 160 = kg/ha).

Status	Mean DM biomass
No competition (vispore)	29.115
Competition	24.625

* The two means are significantly different at $P < 0.01$.

B. Growth Rates

Growth rate analyses were conducted for the entire 1987-88 growing season and from initiation of growth through mid-April 1989 for the 1988-89 growing season. Two separate sets of analyses were conducted. The first included only the perennial grasses with and without competition (uncovered and covered with vispore). The second included the perennial grasses plus the resident annual weeds. For the second set of analyses, the plot design precluded comparing perennial grasses to resident annual weeds on a split-plot basis, so only the uncovered subplots of the perennial grasses were included. Because of the occasional vispore effect the results from the two sets of analyses were occassionally somewhat different with respect to the perennial grasses.

For 1987-88, multivariate ANOVA indicated that site by species interaction effects were significant ($P < 0.01$) for both AGR and RGR in both sets of analyses. The site by competition interaction effects were significant for both AGR and RGR ($P < 0.01$ and $P < 0.05$, respectively) in the perennial grasses only analyses.

When site by species interaction effects were found to be not significant, results and discussion could be conducted on the main effects of each. Insufficient degrees of freedom precluded a multivariate ANOVA for site differences of growth rates during the 1987-88 growing season. Therefore, to reduce the probability of Type I errors (i.e. the error of concluding that two means are different when in fact they are not), P values must be considerably lower than the desired level of significance to be considered significantly different in the univariate analyses of site differences. Species effect was significant ($P < 0.01$) for both AGR and RGR in the 1987-88 analyses.

For 1988-89, multivariate ANOVA indicated that site by species interaction effects were significant ($P < 0.01$) for both AGR and RGR in both sets of analyses. Site effects were significant for both AGR and RGR ($P < 0.10$) when whole plot analyses were conducted, but not significant for either when uncovered subplot analyses were conducted. Species effects were significant ($P < 0.01$) for both AGR and RGR. Competition effects were significant ($P < 0.05$) for both AGR and RGR in the perennial grasses only analysis.

Subsequent to obtaining significant differences in multivariate ANOVA, univariate ANOVAs were conducted for individual growing periods within each growing year.

B.1. Fall Growth Period

Growth initiating rain did not occur until December 1987 which precluded a fall growth period for the 1987-88 growing season. Growth initiating rain arrived in November 1988 and provided a fall growth period for the 1988-89 growing season. Based on precipitation patterns, temperatures and growth patterns, mid-November through mid-December 1988 was categorized as the fall growth period.

B.1.a. Perennial grasses analysis (fall growth period)

Competition was not a factor during the fall growth period. The vispore mulch effect was not apparent and resident annuals did not interfere with perennial grass growth rates.

The site by species interaction effect was found to be significant ($P < 0.01$) for AGR. The overall model for RGR was not significant ($P > 0.10$) during the fall growth period.

The site by species interaction effect for AGR indicated a definite advantage to Site 1 (Table I.10a). Berber orchardgrass had the greatest rate of gain at both sites. The interaction effect was a function of Palestine orchardgrass and Idaho fescue reversing positions at the two sites. Although the two were not significantly different ($P > 0.10$) at either site, Palestine orchardgrass had a higher absolute growth rate at Site 1 and Idaho fescue had a higher absolute growth rate at Site 2. Both wheatgrasses were relatively inactive at both sites during the fall growth period.

Table I.10a. Fall 1988 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) whole plot site by species interaction means. (Grams dry matter per plant * 160 = kg/ha).

17 November - 17 December 1988

Species	Initial DM	AGR		RGR	Final DM
(Site 1)					
Idaho fescue	0.25	.051	b *	.068	1.82
Berber orchardgrass	0.15	.093	a	.155	2.96
Palestine orchardgrass	0.15	.060	b	.110	1.95
Tall wheatgrass	0.00	.002	c	.125	0.05
Intermediate wheatgrass	0.00	.001	c	.095	0.02
(Site 2)					
Idaho fescue	0.18	.032	ab	.096	1.82
Berber orchardgrass	0.16	.052	a	.091	1.68
Palestine orchardgrass	0.05	.013	bc	.105	0.42
Tall wheatgrass	0.00	.002	c	.134	0.07
Intermediate wheatgrass	0.00	.001	c	.104	0.03
S_d, 16 d.f.		.013			

* Within site, means with the same letter are not significantly different at $P < 0.10$.

B.1.b. Perennial grasses and resident annual plant growth rates compared (fall growth period).

When analysis was confined to the uncovered (no vispore) subplots, results among the perennials changed slightly. Although not statistically different, Idaho fescue produced a slightly greater rate of gain than Palestine orchardgrass did at Site 1 (Table I.10b).

The major point of interest was the rate of resident annual plant growth relative to the perennial grasses. At Site 1, resident annual plant growth rate was not significantly different than the orchardgrasses or Idaho fescue. Berber orchardgrass slightly outproduced the annuals during the fall growth period (differences were not statistically significant at $P < 0.10$). At Site 2, the resident annuals significantly outproduced all perennial grasses during the fall growth period.

Although a site by species interaction precludes a formal straightforward site comparison, visual appraisal of the data (Tables I.10a,b) indicates that perennial grasses were considerably more productive at Site 1 than at Site 2 and that resident annuals were considerably more productive at Site 2 than at Site 1 during the fall growth period. Since competition was not a factor, some other explanation is called for. Since the perennial grasses at Site 2 matured and entered dormancy earlier in 1988 than those at Site 1, they experienced a longer quiescent period.

Table I.10b. Fall 1988 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) uncovered subplot site by species interaction means. (Grams dry matter per plant * 160 = kg/ha).

17 November - 17 December 1988

Species	Initial DM	AGR		RGR	Final DM
(Site 1)					
Idaho fescue	0.22	.058	b *	.078	2.02
Berber orchardgrass	0.03	.088	a	.163	2.76
Palestine orchardgrass	0.05	.053	b	.148	1.70
Tall wheatgrass	0.00	.002	c	.128	0.06
Intermediate wheatgrass	0.00	.000	c	.084	0.01
Resident annuals	0.52	.076	ab	.056	2.87
(Site 2)					
Idaho fescue	0.26	.033	bc	.101	1.23
Berber orchardgrass	0.11	.047	b	.103	1.48
Palestine orchardgrass	0.05	.014	c	.137	0.45
Tall wheatgrass	0.00	.003	c	.131	0.07
Intermediate wheatgrass	0.00	.001	c	.102	0.03
Resident annuals	0.25	.087	a	.084	2.76
S_d, 20 d.f.		.012			

* Within site, means with the same letter are not significantly different at $P < 0.10$.

Resources necessary to initiate fall regrowth may have been enough further depleted at Site 2 relative to Site 1 to retard fall regrowth at Site 2. A different, or perhaps an additional, factor may have been the 20 cm soil temperature differences between the two sites. Since Site 1 was consistently warmer than Site 2 at 20 cm, the perennial grasses at Site 1 with established root systems in place may have had an advantage over those at Site 2 when growth initiating rains arrived. At the beginning of the fall period, the 20 cm temperature at Site 1 was 10.7° C and at Site 2 it was 8.9° C. The higher temperature at Site 1 may have been more conducive to root activity than the lower temperature at Site 2. The resident annuals would not yet have had root penetration to the 20 cm depth and so would not have been affected by the 20 cm temperature difference. The longer duration of direct sunlight received each day at Site 2 may have enhanced resident annual production there relative to Site 1.

B.2. <u>Winter Growth Period</u>

The 1988-89 winter growth period was somewhat longer, colder and wetter than the 1987-88 winter growth period. The sampling dates encompassing the 1987-88 winter period were December 11, 1987 and March 12, 1988. During 1988-89, the winter period was encompassed by the December 17, 1988 and April 5, 1989 sampling dates.

B.2.a. Perennial grasses analyses (winter growth period)

Neither the site by species interaction effect nor the site main effect for AGR were significant during the 1987-88 winter growth period. The species main effect was significant ($P < 0.01$). The site by species interaction effect was significant ($P < 0.10$) for RGR. During the 1988-89 winter growth period, the site by species interaction was significant ($P < 0.10$) for AGR and significant ($P < 0.01$) for RGR.

With respect to AGR, trends for the two years were similar, but in 1988-89, the differences were more pronounced (Tables I.11 and I.12). Idaho fescue and the orchardgrasses increased absolute biomass at a greater rate than did the wheatgrasses during the winter growth period in both years. Idaho fescue had a greater rate of biomass accumulation than the orchardgrasses during the winter period of 1988-89 (Table I.12).

With respect to RGR, the trends were different between the two years (Tables I.12 and I.13). During the winter period of 1987-88, RGR tended to be greater for Idaho fescue and the orchardgrasses at Site 1, but differences were not significant at Site 2 (Table I.13). During the winter period of 1988-89, RGRs for the wheatgrasses were greater than for Idaho fescue which was greater than for the orchardgrasses (Table I.12). Intermediate wheatgrass RGR was greater than Tall wheatgrass RGR in 1989. The differences were similar in 1989 for both sites.

Table I.11. Winter (11 December - 12 March) 1987-88 AGR (grams/plant/day) whole plot species main effects.

Species	AGR
Idaho fescue	0.042 a *
Berber orchardgrass	0.040 a
Palestine orchardgrass	0.036 a
Tall wheatgrass	0.022 b
Intermediate wheatgrass	0.016 b

* Mean values with the same letter are not significantly different at $P < 0.10$.

Table I.12. Winter 1988-89 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) whole plot site by species interaction means. (Grams dry matter per plant * 160 = kg/ha).

17 December 1988 - 5 April 1989

Species	Initial DM	AGR	RGR	Final DM
(Site 1)				
Idaho fescue	1.82	.056 a *	.013 c	7.92
Berber orchardgrass	2.96	.028 b	.006 d	5.79
Palestine orchardgrass	1.95	.030 b	.009 d	5.15
Tall wheatgrass	0.05	.026 b	.037 b	2.83
Intermediate wheatgrass	0.02	.018 c	.043 a	2.01
(Site 2)				
Idaho fescue	1.82	.035 a	.014 c	5.00
Berber orchardgrass	1.68	.029 b	.009 d	4.90
Palestine orchardgrass	0.42	.013 c	.012 cd	1.81
Tall wheatgrass	0.07	.007 d	.023 b	0.89
Intermediate wheatgrass	0.03	.010 cd	.034 a	1.13
S_d, 16 d.f.		.008		

* Within site, mean values with the same letter are not significantly different at $P < 0.10$.

Table I.13. Winter 1987-88 beginning and ending weights (grams/plant) and RGR (grams/gram initial weight/day) whole plot site by species interaction means. (Grams per plant * 160 = kg/ha).

11 December 1987 - 12 March 1988

Species	Initial DM	RGR	Final DM
(Site 1)			
Idaho fescue	2.58	0.011 a *	6.76
Berber orchardgrass	2.19	0.012 a	6.15
Palestine orchardgrass	2.89	0.009 ab	6.46
Tall wheatgrass	3.19	0.005 b	4.86
Intermediate wheatgrass	4.06	0.004 b	5.55
(Site 2)			
Idaho fescue	4.44	0.006 a	8.03
Berber orchardgrass	2.51	0.010 a	5.94
Palestine orchardgrass	3.23	0.008 a	6.31
Tall wheatgrass	1.89	0.009 a	4.22
Intermediate wheatgrass	2.57	0.009 a	4.08
s_d, 16 d.f.		0.003	

* Within site, mean values with the same letter are not significantly different at $P < 0.10$.

Throughout this study, RGR had a strong negative relationship with initial size of the plant (i.e. smaller initial plant size resulted in greater RGR). During the winter of 1988-89, with the extreme cold period in February, the trend was pronounced. Those plants with greater above ground biomass had a larger amount of leaf exposure to the cold which may partly explain the pronounced differences in RGR which is based on initial plant size. However, as noted above, absolute biomass accumulation (AGR) was still greater for Idaho fescue and the orchardgrasses (larger plants) than for the wheatgrasses (smaller plants) during the winter growth period.

B.2.b. Competition effects

Competition proved to be a factor for AGR but not for RGR during the winter period of 1988-89. The vispore covered subplots had an AGR of 0.027 grams/plant/day versus an AGR of 0.023 grams/plant/day for the uncovered subplots. The difference was significant at $P < 0.05$. The vispore may have had enough of a moderating effect on temperature to make a difference during the cold spell.

B.2.c. Perennial grass and resident annual plant growth rates compared (winter growth period)

When analyses were confined to the uncovered subplots the site by species interaction effects were significant

($P < 0.01$) for both AGR and RGR during the winter growth period of the 1987-88 season. Neither site by species interaction nor the site main effects for AGR were significant ($P > 0.10$) but the species main effect was significant ($P < 0.01$) during the 1988-89 winter growth period. The site by species interaction effect was significant ($P < 0.01$) for RGR.

With respect to AGR, perennial grasses maintained essentially the same ranking when analysis was confined to the uncovered subplots as they had when whole plots were analyzed. Results were similar for both years and for both sites. Although differences were not always statistically significant and order of rank was not always the same, Idaho fescue ranked first, Berber orchardgrass tended to rank second, Palestine orchardgrass third, and the wheatgrasses trailed (Tables I.11 through I.16).

AGR for the resident annuals was greater than for Idaho fescue during the 1987-88 winter period at Site 2 (Table I.14). Site 2 had an extremely high AGR for the resident annuals in the 1987-88 winter period as a result of a flush of vetch (Vicia spp.) growth. During the 1988-89 winter period, the resident annuals ranked between Idaho fescue and Berber orchardgrass and were not statistically different than either (Table I.15). The extreme cold spell in early February may have had a more severe impact on the resident

Table I.14. Winter 1987-88 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) uncovered subplot site by species interaction means. (Grams dry matter per plant * 160 = kg/ha).

11 December 1987 - 12 March 1988

Species	Initial DM	AGR	RGR	Final DM
(Site 1)				
Idaho fescue	2.60	.049 a *	.011 bc	7.07
Berber orchardgrass	1.80	.048 a	.014 b	6.16
Palestine orchardgrass	2.73	.037 ab	.010 c	6.12
Tall wheatgrass	3.76	.019 b	.004 d	5.45
Intermediate wheatgrass	3.58	.022 b	.005 d	5.54
Resident annuals	0.18	.056 a	.037 a	5.31
(Site 2)				
Idaho fescue	4.94	.038 b	.006 c	8.48
Berber orchardgrass	2.48	.034 b	.009 bc	5.64
Palestine orchardgrass	3.49	.034 b	.007 bc	6.62
Tall wheatgrass	1.79	.024 b	.010 b	4.05
Intermediate wheatgrass	2.31	.019 b	.006 bc	4.03
Resident annuals	0.37	.324 a	.047 a	30.53
S_d, 20 d.f.		.019		

* Within site, means with the same letter are not significantly different at $P < 0.10$.

Table I.15. Winter 1988-89 (17 December - 5 April) AGR (grams/plant/day) uncovered subplot species main effects.

Species	AGR
Idaho fescue	0.043 a *
Berber orchardgrass	0.026 bc
Palestine orchardgrass	0.018 cd
Tall wheatgrass	0.016 cd
Intermediate wheatgrass	0.013 d
Resident annuals	0.037 ab

* Mean values with the same letter are not significantly different at $P < 0.10$.

Table I.16. Winter 1988-89 beginning and ending weights (grams/plant) and RGR (grams/gram initial weight/day) uncovered subplot site by species interaction means. (Grams per plant * 160 = kg/ha).

	17 December 1988 - 5 April 1989		
Species	Initial DM	RGR	Final DM
(Site 1)			
Idaho fescue	2.02	0.012 c *	7.32
Berber orchardgrass	2.76	0.006 d	5.63
Palestine orchardgrass	1.70	0.009 cd	4.32
Tall wheatgrass	0.06	0.036 b	2.88
Intermediate wheatgrass	0.01	0.045 a	1.85
Resident annuals	2.87	0.008 d	7.12
(Site 2)			
Idaho fescue	1.23	0.014 c	5.20
Berber orchardgrass	1.48	0.009 de	4.18
Palestine orchardgrass	0.45	0.012 cd	1.83
Tall wheatgrass	0.08	0.022 b	0.76
Intermediate wheatgrass	0.03	0.033 a	1.09
Resident annuals	2.76	0.007 e	6.51
s_d, 20 d.f.		0.002	

* Within site, mean values with the same letter are not significantly different at $P < 0.10$.

annuals with their relatively shallow root systems at that stage of development than it had on the perennials with more extensive, established root systems in place.

As noted previously, RGR tended to have a negative relationship with initial plant size. This relationship held for the resident annuals as well as for the perennial grasses through the winter growth periods in both years. During 1987-88, with no preceeding fall growth period, the resident annuals were small initially and experienced high RGRs relative to the perennial grasses at both sites. During 1988-89, following a fall growth period, the resident annuals tended to have a greater initial biomass entering the winter growth period and experienced a lower RGR than the perennial grasses.

It is of interest that the wheatgrasses entered the 1987-88 winter growth period with much more initial biomass than they entered the 1988-89 winter period. The July 1987 rain gave the wheatgrasses an opportunity to mature that summer. Late growth initiating rains in 1987 precluded a fall growth period and may have resulted in less initial competition from the resident annuals. The combination of the late summer rain effect on wheatgrass maturity and the late fall rain effect of retarding initiation of resident annual growth may have contributed to the relatively fast start exhibited by the wheatgrasses in 1987-88. In contrast, the summer drought started a month earlier in

1988 and growth initiating rains arrived earlier the following fall. The earlier drought may have contributed to the wheatgrasses not maturing as fully in 1988 as in 1987. Since they did not grow in fall 1988, the wheatgrasses were at an initial competitive disadvantage to the resident annuals relative to the other perennial grasses, all of which did grow. These two factors combined may have contributed to the relatively slow start of the wheatgrasses during the 1988-89 season.

B.3. Early Spring Growth Period

The early spring growth periods roughly corresponded to each other in each of the two years of the study. Early spring 1988 was encompassed by the March 12 and April 15 sampling dates. Following a relatively mild, dry winter, temperatures were moderate with highs generally in the 20°C range and lows ranging from 0° to 10° C. Early spring 1989 was encompassed by the April 5 and April 15 sampling dates. Following a cold, wet winter, temperatures were abruptly warmer with highs approaching 25°C and lows above 5°C.

B.3.a. Competition effects

During the early spring growth period, the vispore began to show an effect on growth rates. Vispore covered subplots had higher AGRs in 1989 and higher RGRs in both 1988 and 1989. Although not significantly different ($P > 0.10$) from the uncovered subplots in 1988, the vispore covered subplots followed the same trend of higher absolute growth rates (Table I.17).

B.3.b. Perennial grasses analyses (early spring growth period)

Neither the site by species interaction effect nor the site main effect for either AGR or RGR were significant ($P > 0.10$) during the 1988 early spring growth period. For both rates, species main effects were significant ($P < 0.01$). During the 1989 early spring growth period, the site by species interaction effects were significant ($P < 0.01$) for both AGR and RGR.

With respect to perennial grass AGRs, trends for the two years were similar. Idaho fescue clearly dominated the others in terms of absolute biomass accumulation (Tables I.18 and I.19). The orchardgrasses, particularly Palestine, tended to lag behind the others. In 1989, negative numbers indicate that little or no growth occurred for Palestine orchardgrass at Site 1 and for Berber orchardgrass at Site 2. In 1988, AGRs of the wheatgrasses were sufficient to catch up with the orchardgrasses in terms of biomass accumulation (Table I.18). In 1989, the wheatgrasses started out further behind and were not able to catch the orchardgrasses, but they were able to close the gap (Table I.19).

With respect to perennial grass RGRs, trends for the two years were also similar. With the exception of Idaho fescue, species with smaller initial size maintained the trend noted earlier of having the higher RGRs. Idaho

Table I.17. Early spring growth period competition effects for both AGR (grams/plant/day) and RGR (grams/initial gram of plant/day).

Year	Status	AGR	RGR
1988 (12 March - 15 April)	No competition (vispore)	.117 a *	.016 a
	Competition	.101 a	.012 b
1989 (5 April - 15 April)	No competition (vispore)	.072 a	.022 a
	Competition	.037 b	.015 b

* Mean values with the same letter within both the same year and type of growth rate are not significantly different at $P < 0.10$.

Table I.18. Early spring 1988 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) whole plot species main effects. (Grams dry matter per plant * 160 = kg/ha).

12 March - 15 April 1988

Species	Initial DM	AGR	RGR	Final DM
Idaho fescue	7.39	.230 a *	.022 a	14.52
Berber orchardgrass	6.05	.080 bc	.011 c	8.50
Palestine orchardgrass	6.38	.048 c	.007 c	7.86
Tall wheatgrass	4.54	.091 b	.015 b	7.38
Intermediate wheatgrass	4.81	.095 b	.016 b	7.75

* Mean values in a column with the same letter are not significantly different at $P < 0.10$.

Table I.19. Early spring 1989 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) whole plot site by species interaction means. (Grams dry matter per plant * 160 = kg/ha).

5 - 15 April 1989

Species	Initial DM	AGR	RGR	Final DM
(Site 1)				
Idaho fescue	7.92	.204 a *	.021 ab	10.17
Berber orchardgrass	5.79	.073 b	.012 abc	6.61
Palestine orchardgrass	5.14	-.010 b	-.002 c	5.04
Tall wheatgrass	2.83	.105 b	.031 ab	3.98
Intermediate wheatgrass	2.01	.093 b	.035 a	3.03
(Site 2)				
Idaho fescue	5.00	.034 a	.005 bc	5.31
Berber orchardgrass	4.90	-.075 b	-.015 c	4.22
Palestine orchardgrass	1.81	.004 a	.007 bc	1.85
Tall wheatgrass	0.89	.067 a	.054 a	1.49
Intermediate wheatgrass	1.43	.050 a	.034 ab	1.58
S_d, 16 d.f.		.013		

* Within site, means with the same letter are not significantly different at $P < 0.10$.

fescue was an interesting exception. In 1988, it had a significantly higher ($P < 0.10$) RGR than the others in spite of starting with a greater biomass (Table I.18). In 1989, Idaho fescue did lag behind the wheatgrasses in RGR at Site 2, but was not statistically different at Site 1. However, it again had a substantially greater initial biomass. During this period, Idaho fescue plants had entered the boot stage of phenology at both sites in 1988 and at Site 1 in 1989. Fewer plants had entered the boot stage at Site 2 in 1989. The reproductive culm elongation associated with this period may have been largely responsible for the high RGR exhibited by Idaho fescue in spite of its high initial weight during the early spring period. Several Berber orchardgrass plants at Site 1 were in the boot stage by the end of the early spring period in 1989, however, reproductive culm elongation had not yet occurred. Berber orchardgrass had not yet achieved the boot stage by the end of early spring in 1988. This may have accounted for the relative improvement in RGR for Berber orchardgrass from 1988 to 1989 for the early spring periods.

B.3.c. Perennial grass and resident annual plant growth rates compared (early spring growth period)

When analyses were confined to uncovered subplots, results among the perennial grasses remained similar to results from whole plot analyses described above. Growth rates for the resident annuals were quite different at the two sites and between the two years (Tables I.20 and I.21). By the 1988 early spring growth period at Site 2, the winter flush of vetch (Vicia spp.) growth was over. The negative growth rate during the spring period did not reflect no growth, but rather growth of a different set of annual plants that did not achieve the same biomass levels of the earlier vetch. Site 2 in 1989 did not have the same flush of winter growth that occurred in 1988, but it did have a strong early spring flush of growth. AGR was significantly higher ($P < 0.10$) for the resident annuals than for any of the perennials at Site 2. RGR was also significantly higher ($P < 0.10$) for the resident annuals at Site 2 than for the perennial grasses with the exception of Tall wheatgrass which started with a much lower initial biomass (Table I.21). At Site 1, resident annual plant growth rates were similar to or less than the perennial grasses in both years. Perennial grasses at Site 1 did not suffer from the same degree of competitive interference from the resident annuals that characterized Site 2 in either year.

B.4. Spring and Summer Growth Periods

Sampling was terminated following April 15, 1989, therefore, spring and summer growth rates were evaluated only for 1988.

Table I.20. Early spring 1988 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) uncovered subplot site by species interaction means. (Grams dry matter per plant * 160 = kg/ha).

12 March - 15 April 1988

Species	Initial DM	AGR	RGR	Final DM
(Site 1)				
Idaho fescue	7.07	.207 a *	.021 a	13.69
Berber orchardgrass	6.16	.039 b	.006 c	7.41
Palestine orchardgrass	6.12	.025 b	.004 c	6.91
Tall wheatgrass	5.45	.102 ab	.014 b	8.70
Intermediate wheatgrass	5.54	.091 b	.013 b	8.44
Resident annuals	5.31	.041 b	.007 c	6.62
(Site 2)				
Idaho fescue	8.48	.266 a	.022 a	16.47
Berber orchardgrass	5.64	.107 b	.014 bc	8.86
Palestine orchardgrass	6.62	.027 b	.004 c	7.43
Tall wheatgrass	4.05	.050 b	.010 bc	5.55
Intermediate wheatgrass	4.03	.096 b	.017 ab	6.91
Resident annuals	30.53	-.498 c	-.022 d	16.09
S_d, 20 d.f.		.063	.004	

* Within site, means with the same letter are not significantly different at $P < 0.10$.

Table I.21. Early spring 1989 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) uncovered subplot site by species interaction means. (Grams dry matter per plant * 160 = kg/ha).

5 - 15 April 1989

Species	Initial DM	AGR	RGR	Final DM
(Site 1)				
Idaho fescue	7.32	.112 a *	.013 b	8.55
Berber orchardgrass	5.63	.065 a	.013 b	6.35
Palestine orchardgrass	4.32	-.028 b	-.006 c	4.02
Tall wheatgrass	2.88	.079 a	.025 ab	3.75
Intermediate wheatgrass	1.85	.080 a	.033 a	2.73
Resident annuals	7.12	-.085 b	-.015 c	6.19
(Site 2)				
Idaho fescue	5.20	.045 b	.007 bc	5.60
Berber orchardgrass	4.18	-.076 c	-.020 d	3.50
Palestine orchardgrass	1.83	-.004 bc	-.005 cd	1.79
Tall wheatgrass	0.76	.065 b	.063 a	1.34
Intermediate wheatgrass	1.09	.032 b	.024 b	1.38
Resident annuals	6.51	.380 a	.050 a	9.93
S_d, 20 d.f.		.055	.010	

* Within site, means with the same letter are not significantly different at $P < 0.10$.

Following a relatively dry winter and early spring, spring 1988 received adequate and well distributed precipitation. The last two weeks of May were relatively dry followed by a wet first ten days of June. After June 10, there was effectively no precipitation through the balance of the growing season. Daily maximum temperatures were generally below 30°C through mid-June, in the low to mid-thirties through mid-July, and in the upper thirties and low forties celcius through mid-August by which time Tall wheatgrass, the latest maturing of the perennial grasses, had stopped growing.

B.4.a. Competition effects during the spring and summer growth periods

Effects due to competition were significant for both AGR (grams/plant/day) and RGR (grams/gram/day) only during the 15 April - 12 May and 12 May - 24 May growing periods. During the spring periods vispore protected plants outproduced those subject to competition on both AGR and RGR bases (Table I.22). These periods covered the time in which the resident annual weeds were growing most rapidly and provided the greatest degree of interference. A site by competition interaction occurred during the 15 April - 12 May period when Site 2 received the additional benefit from the vispore relative to Site 1. Resident annual production was greater at Site 2 than at Site 1 and presumably provided greater competitive interference to the perennial

Table I.22. Competition vs. no competition effects on AGR and RGR during mid and late spring growing periods. Means represent all five selected species at both sites.

	15 April - 12 May		12 May - 24 May	
Status	AGR	RGR	AGR	RGR
No competition (vispore)	0.251 *	0.019	0.399	0.020
Competition	0.182	0.016	0.250	0.015

* All competition vs. no competition differences are significant at $P < 0.01$.

grasses.

B.4.b. Spring and Summer Growth Periods

During the 15 April - 12 May period, Idaho fescue and the orchardgrasses completed the transition from vegetative to reproductive status and nearly all plants had formed seed heads by the end of the period. During this period the wheatgrasses entered the reproductive culm elongation phase of development. Idaho fescue and the wheatgrasses tended to outproduce the orchardgrasses on both AGR and RGR bases (Table I.23). Relative to the previous period, all five perennial grasses accelerated AGRs at Site 2; the wheatgrasses and Palestine orchardgrass accelerated RGRs at Site 2; and, the wheatgrasses and Palestine orchardgrass accelerated AGRs at Site 1.

During the 12 - 24 May period, Idaho fescue was in full anthesis, many of the orchardgrasses had begun anthesis, Intermediate wheatgrass was beginning to enter the boot stage and Tall wheatgrass was still in the reproductive culm elongation phase. During this period, the orchardgrasses had consistently greater AGR and RGR than Idaho fescue and the wheatgrasses (Table I.24).

During the 24 May - 7 June period following a relatively dry two weeks, growth had slowed for all perennial grasses except Intermediate wheatgrass (Table I.25).

Table I.23. Spring and summer 1988 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) whole plot site by species interaction means. (Grams dry matter per plant * 160 = kg/ha).

15 April - 12 May 1988

Species	Initial DM	AGR	RGR	Final DM
(Site 1)				
Idaho fescue	13.96	.205 a *	.012 b	20.11
Berber orchardgrass	8.07	.090 b	.010 b	10.76
Palestine orchardgrass	7.78	.088 b	.009 b	10.43
Tall wheatgrass	8.30	.193 a	.018 a	14.09
Intermediate wheatgrass	8.20	.122 b	.012 b	11.85
(Site 2)				
Idaho fescue	15.08	.418 a	.021 b	27.62
Berber orchardgrass	8.92	.138 d	.012 c	13.07
Palestine orchardgrass	7.94	.246 c	.022 b	15.33
Tall wheatgrass	6.74	.316 bc	.030 a	15.94
Intermediate wheatgrass	7.30	.347 b	.030 a	17.70
S_d, 16 d.f.		.041	.003	

* Within site, mean values with the same letter are not significantly different at $P < 0.10$.

Table I.24. Spring and summer 1988 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) whole plot site by species interaction means. (Grams dry matter per plant * 160 = kg/ha).

12 May - 24 May 1988

Species	Initial DM	AGR	RGR	Final DM
(Site 1)				
Idaho fescue	20.11	.172 bc *	.008 b	22.01
Berber orchardgrass	10.76	.429 ab	.032 a	15.48
Palestine orchardgrass	10.43	.630 a	.047 a	17.36
Tall wheatgrass	14.09	.040 c	.002 b	14.53
Intermediate wheatgrass	11.85	.056 c	.004 b	12.47
(Site 2)				
Idaho fescue	27.62	.689 a	.022 a	35.20
Berber orchardgrass	13.07	.621 a	.037 a	19.91
Palestine orchardgrass	15.33	.775 a	.038 a	23.85
Tall wheatgrass	15.94	.054 b	.003 b	16.54
Intermediate wheatgrass	17.70	-.347 b	-.030 c	15.21
S_d, 16 d.f.		.195	.010	

* Within site, mean values with the same letter are not significantly different at $P < 0.10$.

Table I.25. Spring and summer 1988 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) whole plot site by species interaction means. (Grams dry matter per plant * 160 = kg/ha).

24 May - 7 June 1988

Species	Initial DM	AGR	RGR	Final DM
(Site 1)				
Idaho fescue	22.01	-.172 bc*	-.005 c	20.50
Berber orchardgrass	15.48	.244 a	.014 b	19.14
Palestine orchardgrass	17.36	.000 b	.000 c	17.36
Tall wheatgrass	14.53	.237 a	.014 b	18.08
Intermediate wheatgrass	15.21	.363 a	.024 a	17.92
(Site 2)				
Idaho fescue	35.20	-.246 c	-.008 d	31.51
Berber orchardgrass	19.91	-.063 a	-.003 cd	18.96
Palestine orchardgrass	23.85	.050 b	.003 bc	24.60
Tall wheatgrass	16.54	.039 b	.002 bc	17.12
Intermediate wheatgrass	15.21	.523 a	.026 a	23.06
S_d, 16 d.f.		.109	.005	

* Within site, mean values with the same letter are not significantly different at $P < 0.10$.

During the 7 - 14 June period all grasses, except Tall wheatgrass at Site 1, were able to capitalize on the additional moisture as a result of the early June rains (Table I.26).

During the 14 - 28 June period, growth had slowed for all grasses at Site 1 and, with the exception of Tall wheatgrass, weight loss had occurred at Site 2. Since weed growth was not a factor during this period, slower growth during the previous period may have resulted in conservation of sufficient moisture to allow continued growth of Tall wheatgrass at Site 2 (Table I.27).

B.5. Growth Rates Summary of Results

Competition (vispore covered vs uncovered subplots) was a factor during the 1988-89 winter growth period and during the spring growth periods for both years. In those periods, plants that received the vispore mulch and weed suppression effects outproduced those plants not protected by the vispore. Spring was the time in which the resident annual weeds were growing most rapidly and inflicted the greatest degree of competitive interference.

During the fall growth period, Site 1 had a greater AGR than did Site 2. Higher soil temperatures at 20 cm depth may have been a factor. Of the perennial grasses, Berber orchardgrass had the greatest rate of gain at both sites followed by Idaho fescue and Palestine orchardgrass. The wheatgrasses were inactive. At Site 1, the resident annual

Table I.26. Spring and summer 1988 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) whole plot site by species interaction means. (Grams dry matter per plant * 160 = kg/ha).

7 June - 14 June 1988

Species	Initial DM	AGR	RGR	Final DM
(Site 1)				
Idaho fescue	20.50	.175 a *	.007 ab	21.37
Berber orchardgrass	19.14	.366 a	.013 ab	20.97
Palestine orchardgrass	17.36	.548 a	.030 a	18.22
Tall wheatgrass	18.08	.042 a	.000 b	18.30
Intermediate wheatgrass	17.92	.542 a	.028 a	20.63
(Site 2)				
Idaho fescue	31.51	1.413 a	.039 bc	41.41
Berber orchardgrass	18.96	1.915 a	.080 a	32.37
Palestine orchardgrass	25.60	.594 b	.023 c	28.76
Tall wheatgrass	17.12	.039 b	.028 bc	20.96
Intermediate wheatgrass	23.06	1.440 a	.053 ab	33.14
S_d, 16 d.f.		.391	.016	

* Within site, mean values with the same letter are not significantly different at $P < 0.10$.

Table I.27. Spring and summer 1988 beginning and ending weights (grams per plant), AGRs (grams/plant/day) and RGRs (grams/gram of initial weight/day) whole plot site by species interaction means. (Grams dry matter per plant * 160 = kg/ha).

14 June - 28 June 1988

Species	Initial DM	AGR	RGR	Final DM
(Site 1)				
Idaho fescue	21.37	-.444 b *	-.026 b	15.61
Berber orchardgrass	20.97	.068 a	.004 a	21.85
Palestine orchardgrass	18.22	.095 a	.002 a	21.33
Tall wheatgrass	18.30	.039 a	.002 a	18.81
Intermediate wheatgrass	20.63	.152 a	.006 a	22.60
(Site 2)				
Idaho fescue	41.41	-.664 c	-.019 b	32.11
Berber orchardgrass	32.37	-.510 bc	-.019 b	24.07
Palestine orchardgrass	28.76	-.189 b	-.007 b	25.22
Tall wheatgrass	20.96	.326 a	.015 a	25.52
Intermediate wheatgrass	33.14	-.172 b	-.005 b	30.73
S_d, 16 d.f.		.214	.008	

* Within site, mean values with the same letter are not significantly different at $P < 0.10$.

AGR was not significantly different than the orchardgrasses or Idaho fescue. At Site 2, the resident annuals significantly outproduced all perennial grasses during the fall growth period.

During the winter growth periods, site was a factor in 1988-89. Site 1 had a greater AGR than Site 2. Again, higher soil temperatures at 20 cm depth may have been a factor. Idaho fescue and the orchardgrasses increased absolute biomass at a greater rate than did the wheatgrasses in both years at both sites. Resident annual growth rates were higher than perennial grass growth rates during the mild 1987-88 winter period. During the cold 1989 winter period, resident annual growth rates were not statistically different than Idaho fescue or the orchardgrasses.

Early spring growth rates were dominated by Idaho fescue. The orchardgrasses lagged behind the wheatgrasses. Resident annual plant growth was greater than perennial grass growth rates at Site 2 but about the same at Site 1.

During the spring and summer periods, growth rates for the various perennial grasses shifted in ranking as their stages of phenological development changed. Idaho fescue was the earliest to mature followed by Berber orchardgrass, Palestine orchardgrass, Intermediate wheatgrass and, finally, Tall wheatgrass. By late spring, yellow starthistle was the only resident annual left in production.

Throughout the study, RGR had a strong negative relationship with initial plant size. With one exception, smaller initial plant size resulted in greater RGR. Idaho fescue RGRs during the early spring periods in both years were the exceptions. In 1988, Idaho fescue had a significantly greater RGR than the others in spite of starting with a greater biomass. In 1989, it did lag behind the wheatgrasses at Site 2 but was not statistically different at Site 1. Again, Idaho fescue started the 1989 early spring period with a greater biomass than the others.

Conclusions

Peak Standing Crops

Both 1987 and 1988 received late growing season moisture (early July in 1987 and early June in 1988). It appears that with late season moisture, production potential at Site 2 is greater than at Site 1. With late spring, early summer moisture, as in 1988, the earlier maturing grasses benefitted since they had not yet completely matured and could take advantage of the additional late moisture to fill out seed. With mid-summer moisture additions, as in 1987, the later maturing plants (e.g. Tall wheatgrass) that had not yet matured were able to capitalize on the additional moisture to fill out seed. Having been preceeded by an extended dry period, as in

1987, the earlier maturing grasses were no longer able to capitalize on the additional moisture. Since late spring, early summer precipitation is more frequent than late summer precipitation at these sites, earlier maturing grasses should generally have an advantage in terms of total production. Results from 1988 supported this conclusion.

Although slope, aspect and soils were all different, and therefore confounded, between the two sites, a conjectural explanation of the superiority of production potential at Site 2 is in order. Because of the difference in slope and aspect, Site 2 received a longer period of sunlight per day, particularly in the morning when temperatures are moderate during spring and summer. In 1988, growth rates at Site 2 acclerated rapidly relative to Site 1 in the late spring, early summer period. The longer exposure to direct sunlight, particularly under moderate temperatures, could largely explain the divergence in growth rates between the two sites at that time. The perennial grasses were also more advanced phenologically at Site 2 and the early June precipitation enabled them to complete their development to maturity. The wheatgrasses, particularly Tall wheatgrass, did not reach full maturity at Site 1.

The more rapid phenological development at Site 2 relative to Site 1 was probably also largely due to the longer period of direct sunlight received each day including the mornings with their moderate temperatures. The advanced phenology, when coupled with late spring, early summer precipitation, resulted in perennial grasses at Site 2 achieving maturity earlier than at Site 1. More rapid phenological development through the spring and early summer is probably a common occurrence at Site 2 relative to Site 1.

The same explanation may have accounted for the different species composition and greater biomass production of the resident annual population at Site 2 relative to Site 1.

Growth Rates

Much of the shifting of growth rates among species appears to have been due to timing of phenological development. Temperature and moisture conditions provided variable growing and development conditions. Based on historical climate patterns those perennial grasses capable of growing during the winter period should have an advantage in most years. Once established they should be able to effectively compete with the resident annuals for resources which would enable them to maintain a stand. In this study timing of growth and phenological development occurred from earliest to latest in the following order:

Idaho fescue < Berber orchardgrass < Palestine orchardgrass < Intermediate wheatgrass < Tall wheatgrass

Long-term production and stand maintenance potentials would be expected to follow the same order. During the 1988 winter growth period, rates of gain on a per day basis were small, however, over a period of time an advantage in terms of accumulated biomass became established. Idaho fescue and the orchardgrasses were then able to complete their development through maturity prior to the onset of summer drought. Through the winter and early spring of 1989, Idaho fescue and Berber orchardgrass exhibited the fastest rates of growth, had the lowest mortality rates and had the most uniform stands at both sites. Palestine orchardgrass, although slower than Idaho fescue and Berber orchardgrass, experienced earlier growth than did the wheatgrasses. Several Palestine orchardgrass and several of the later maturing wheatgrass plants suffered mortality at Site 2 following the 1988 growing season. These results have suggested that the conclusions reached by Jackson and Roy (1986) may have application to this study and to southwest Oregon foothills in general. The earlier and longer period of drought at Site 2 may have been at least partly responsible for slower autumn regrowth and lower vigor at Site 2 relative to Site 1. The higher rate of mortality at Site 2 may have been a result.

Stand maintenance potential can be fully assessed only after a number of years of evaluation. The ability of a species to maintain a stand will be a function more of the extreme stress years than of the average years or of those years with better than normal precipitation distribution. Based on historical records, the July 1987 precipitation event was an aberation, and June precipitation, as in 1988, can not be counted on. It will be the occassional early, severe drought years that will determine which perennial grasses are best suited to the area. It is my opinion that those grasses able to initiate growth earliest, to continue at least some growth through the winter and to mature earliest will be the grasses that maintain long-term production potential. They may not be the grasses that provide the best production potential in an average or good year. In this study, the two grasses that best fit the above description are the native Idaho fescue and the introduced Berber orchardgrass. Of the perennial grasses included in the study, these two have the growth patterns that appear to be necessary for stand maintenance in the southwestern Oregon foothills. Palestine orchardgrass may have good potential, particularly in low average to good precipitation distribution years. The wheatgrasses have high production potential in those above average to good precipitation distribution years as was evident in this study, especially 1987. The wheatgrasses may also require sites with less weed competition than occurs at Site 2.

Site Adaptability

The native Idaho fescue is currently found in association with oak trees. Prior to this study it was not known if it required a modified microenvironment to maintain a stand or if its position has been a function of an inability to establish from seed in the open when competing with the resident annuals. Idaho fescue plants transplanted into the plots, which were in the open, have been very productive once established. Thus it can be concluded that at least some of the native perennial grasses with growth patterns adapted to the climate of the region are capable of maintaining a stand in the open if they can become established. Results of this study have tended to support the conclusion that both the ability to grow during the winter months and early maturity are necessary traits for perennial grasses to maintain site dominance over the resident annuals and to be consistently productive.

CHAPTER II

TIMING AND EXTENT OF SOIL MOISTURE EXTRACTION BY VEGETATION IN A MEDITERRANEAN/MARITIME REGIME

Introduction

In a Mediterranean type system successful plants would either access soil moisture from a different level than others or would have to be successful competitors for available soil moisture during the spring and early summer when temperatures are optimum for growth but soil moisture is generally becoming increasingly limited. In evaluating native and introduced perennial grasses for their adaptability to the climate and soils of southwest Oregon foothills, an important consideration is the timing and extent of soil moisture extraction. Since in a Mediterranean system growing conditions are optimum during the spring and early summer and since the onset of summer drought can be early and is often severe, plants able to extract soil moisture early should have a long-term competitive advantage over those active later.

Eissenstat (1986) and Eissenstat and Caldwell (1988) found that the success of indicator plants in the Great Basin could be related to the ability of monospecific stands of test species to extract soil moisture under similar conditions. They found species differences in the rate of water extraction and in the ability to maintain differences through the sampling period. In a related study, Thorgeirsson (1985) monitored timing, rate and depth of soil moisture extraction in monocultures of *Agropyron desertorum* and *A. spicatum* and in grass-shrub mixtures of each with *Artemisia tridentata*. Davis and Mooney (1986) examined the possibility of root stratification promoting a sharing of soil moisture resources by comparing seasonal water use patterns in a mixed stand of chaparral dominated by different shrubs. Cable (1968) found differences in water use among species, among seasons and at various depths. He was able to describe relative competitive abilities among the species on the basis of timing of soil moisture utilization and depth from which moisture was being extracted at any given time.

The primary objectives of this research were: 1) to examine timing of soil moisture extraction by selected perennial grasses and the resident annual community through the periods of active growth, and 2) to examine the extent of soil moisture extraction.

Materials and Methods

Study Site

The study was conducted at two foothills sites in Jackson County in southwest Oregon. Site 1 is located 3 km east of Phoenix on the Bob Ferns ranch and Site 2 is located about 5 km northeast of Ashland on the Joe Dauenhauer ranch. Soils at the two sites are Darrow silty clay loam and Carney clay, respectively; aspects are west and southwest, respectively; and slopes are 20-35% (mid slope) and 5-20% (toe slope), respectively. The area is characterized by a Mediterranean/Maritime climate pattern with cool wet winters and hot dry summers. Annual precipitation averages 500 - 600 mm at both sites, but distribution and quantity vary considerably from year to year. On average approximately 82% of the precipitation falls between 1 October and 30 April, 4.8% in May, 2.3% in June and 0.7% in July. The average January temperature is 3.3°C and the average July temperature is 21.1°C. Extreme temperatures range from -20°C to 41°C.

Plot Design

Selected perennial grasses were transplanted into plots during the fall and winter of 1986-87 and allowed to establish in the absence of competition during the 1986-87 growing season. Supression of competition was accomplished by transplanting into plots covered with vispore, a black plasic sheeting. The vispore has 400 holes per square inch to allow water and air passage. Following establishment during the first growing season, the plots were split by removing the vispore from half of each plot. The resident annuals were thus allowed to provide competition for the perennials on half of each plot while the perennials remained competition free on the other half. Plants growing competition free provided an assessment of growth and soil moisture extraction potentials on the sites. Open plots void of vegetation were included in each block to provide an estimate of soil moisture loss due to factors other than transpiration (e.g. evaporation). Split open plots also provided an estimate of vispore (mulch) effect on soil moisture loss.

Experimental Design and Analysis

The study was replicated at two sites within the Rogue River Valley. The plot layout within each site consisted of three blocks each of which contained randomly assigned perennial grass species and control subplots. Each perennial grass and control subplot was further divided into randomly assigned with and without competition sub-subplots. The data were then analyzed using a split-split-plot ANOVA model:

Source	d.f.
Site	(a-1)
Block (Site)	(b-1)a
Species	(c-1)
Site * Species	(a-1)(c-1)
Species * Block (Site)	(c-1)(b-1)(a)
Competition	(d-1)
Competition * Site	(d-1)(a-1)
Competition * Species	(d-1)(c-1)
Competition * Site * Species	(d-1)(a-1)(c-1)
Competition * Block (Site) + Competition * Species * Block (Site)	(d-1)(b-1)(a) + (d-1)(c-1)(b-1)(a)

Each site was analyzed as a whole plot, each species and control as a subplot within site, and competition as a sub-subplot within species, within site. Since Block 1 at Site 1 was not necessarily the same as Block 1 at Site 2, block was nested within site (i.e. Block (Site)) for the analysis rather than treated separately. Block (Site) (i.e. block nested within site) served as the error term for Site. Species * Block (Site) served as the error term for Species and Site * Species. The last term of the model served as the expermimental error term for Competition and Competition interactions.

To account for auto-correlation of dates of sampling, multivariate ANOVA was first conducted to provide a conservative screen for significant differences. Univariate analysis followed when differences were detected. An F-protected LSD was used following a significant F-ratio of at least the $P \leq 0.10$ level.

Neutron Access Tube Installation

Neutron probe access tubes were installed at both sites on April 12, 1987 in plots of the following species: Idaho fescue (*Festuca idahoensis*), Berber and Palestine orchardgrasses (*Dactylis glomerata* varieties 'Berber' and 'Palestine'), California oatgrass (*Danthonia californica*), and in plots referred to as Open which were void of vegetation. On July 23, 1987, access tubes were added outside the plots among undisturbed resident annuals parallel to and corresponding to the blocks in the plots. Additional access tubes were installed in Intermediate wheatgrass (Agropyron intermedium) plots at both sites on August 6, 1987. The final complement of access tubes were installed in Tall wheatgrass (Agropyron elongatum) plots at both sites on May 4, 1988. Two access tubes were placed in each plot to correspond to subplots once the main plots were split. Information was thus available for each of the perennial grasses in the absence of competition and with the advantage of a mulch effect (i.e. vispore), for each of the perennial grasses subject to competition by resident annuals, in plots void of vegetation with and without a mulch protection (i.e. vispore), and for undisturbed resident annuals.

Sampling

Following early July rains that provided some soil moisture recharge and resulted in continued growth of the perennial grasses, sampling was initiated on July 23, 1987 and continued weekly through August 24, 1987. Neutron probe readings were taken at 15, 30 and 60 cm depths. Readings were taken again in October prior to the onset of fall precipitation.

During 1988 a malfunctioning neutron probe battery pack precluded sampling prior to May 20, 1988 when sampling for the 1988 growing season was initiated. Readings were then taken weekly with the exception of the end of the first week in June because of rain. Sampling was continued through the first week in August when the last of the perennial grasses, Tall wheatgrass, completed growth. Beginning with the 1988 season, readings were taken at 15, 30, 45 and 60 cm depths.

Beginning in mid-October 1988, readings were taken monthly through mid-March 1989 then bi-weekly through mid-April when this portion of the study was completed.

Soil moisture retention determinations were obtained for both sites at depths of 15, 30, 45 and 60 cm by the Soil Physics Lab, Dept. of Soil Science, Oregon State University. The pressure-plate technique was used. Pressure-plate technique problems were encountered as a result of the extreme shrink-swell potential of the soils and rendered the results unreliable.

Results and Discussion

A. Fall Growth Period

Within the time frame of this study, the only fall growth period occurred from mid-November through mid-December 1988. A preseason soil moisture status sampling was conducted on October 16, 1988 prior to any fall precipitation or plant growth.

Site differences were significant ($P < 0.10$) at 15, 30 and 45 cm (Table II.1). Site 1 had a consistently higher count ratio (measure count/standard count) than did Site 2. Plot (species) differences were significant at all four

Table II.1. Preseason (October 16, 1988) site comparison of neutron probe count ratios (measure count/standard count). % vol. is percent volumetric soil moisture as calculated from the count ratio.

	Site 1		Site 2	
Depth (cm)	Count ratio	% vol.	Count ratio	% vol.
15	.264 a *	7.56	.213 b	4.32
30	.389 a	15.48	.338 b	12.25
45	.432 a	18.21	.399 b	16.12
60	.461 a	20.05	.445 a	19.03

* Within depth (row), count ratio site means with the same letter are not significant at $P < 0.10$.

depths sampled (15, 30, 45 and 60 cm) (Table II.2). At all four depths, the Open plots (no vegetation) had consistently more soil moisture than did any of the occupied plots. Among the occupied plots at 15 cm, soil moisture contents from highest to lowest were Idaho fescue, Berber orchardgrass, Tall wheatgrass, Palestine orchardgrass, Intermediate wheatgrass and resident annuals (Table II.2). Differences among those plots occupied by plants were not significant ($P > 0.10$) at 30, 45 or 60 cm depths.

By mid-December, following precipitation accumulations of 11.8 and 11.0 cm at Sites 1 and 2, respectively, site differences at 15 and 30 cm had been eliminated (Table II.3). At 45 cm, the site difference persisted. At 60 cm, a site difference had developed. Infiltration to 60 cm was greater at Site 1 than at Site 2.

Plots differences among the species at 15 cm were negligible by mid-December. The low soil moisture level at 45 cm for the resident annuals plots at Site 2 may reflect the rapid growth of the resident annuals and the withdrawl of enough moisture to retard infiltration to that depth. A similar difference did not occur at Site 1 where resident annual growth was at the same rate as perennial grass growth rates (Chapter I.B.1). At Site 2, the similarity between resident annuals plots and perennial grasses plots at 60 cm depth would reflect a carryover from the previous

Table II.2. Preseason (October 16, 1988) species comparison of neutron probe count ratios (measure count/standard count). % vol. is percent volumetric soil moisture calculated from the count ratio.

	15 cm		30 cm	
Species	Count ratio	% vol.	Count ratio	% vol.
Idaho fescue	0.253 b *	6.86	0.352 b	13.14
Berber orchardgrass	0.240 bc	6.03	0.353 b	13.20
Palestine orchardgrass	0.220 cd	4.76	0.320 b	11.11
Tall wheatgrass	0.239 bc	5.97	0.344 b	12.63
Intermediate wheatgrass	0.214 d	4.38	0.329 b	11.68
Resident annuals	0.176 d	1.97	0.305 b	10.16
Open (no vegetation)	0.303 a	10.03	0.507 a	22.97

	45 cm		60 cm	
Species	Count ratio	% vol.	Count ratio	% vol.
Idaho fescue	0.385 b	15.23	0.418 b	17.32
Berber orchardgrass	0.398 b	16.05	0.436 b	18.46
Palestine orchardgrass	0.377 b	14.72	0.427 b	17.89
Tall wheatgrass	0.396 b	15.93	0.432 b	18.21
Intermediate wheatgrass	0.382 b	15.04	0.424 b	17.70
Resident annuals	0.395 b	15.86	0.449 b	19.29
Open (no vegetation)	0.563 a	26.52	0.583 a	27.79

* Within depth, the same letters indicate no significant differences among species at $P < 0.10$.

Table II.3. Fall (December 8, 1988) site by species neutron probe mean count ratios (measure count/standard count) comparison within depth. % vol. is percent volumetric soil moisture as calculated from the count ratio.

	15 cm		30 cm		45 cm		60 cm	
Species	Count ratio	% vol.	Count ratio	% vol.	Count ratio	% vol.	Count ratio	% vol.
(Site 1)								
Idaho fescue	0.556 a *	26.07	0.604 a	29.12	0.583 a	27.79	0.536 b	24.81
Berber orchardgrass	0.564 a	26.58	0.611 a	29.56	0.596 a	28.61	0.533 b	24.62
Palestine orchardgrass	0.545 ab	25.38	0.602 a	28.99	0.582 a	27.72	0.554 ab	25.95
Tall wheatgrass	0.549 ab	25.63	0.593 a	28.42	0.572 a	27.09	0.520 b	23.79
Intermediate wheatgrass	0.547 ab	25.50	0.594 a	28.48	0.555 a	26.01	0.510 b	23.16
Resident annuals	0.508 b	23.03	0.588 a	28.10	0.575 a	27.28	0.520 b	23.79
Open (no vegetation)	0.546 ab	25.44	0.593 a	28.42	0.604 a	29.12	0.611 a	29.56
Site 1 average	0.545 A **	25.38	0.598 A	28.74	0.581 A	27.66	0.541 A	25.12
(Site 2)								
Idaho fescue	0.589 a	28.17	0.632 a	30.89	0.519 b	23.73	0.446 b	19.10
Berber orchardgrass	0.576 ab	27.34	0.605 ab	29.18	0.464 bc	20.24	0.448 b	19.22
Palestine orchardgrass	0.559 ab	26.26	0.602 ab	28.99	0.478 bc	21.13	0.439 b	18.65
Tall wheatgrass	0.569 ab	26.90	0.601 ab	28.93	0.513 b	23.35	0.460 b	19.99
Intermediate wheatgrass	0.545 b	25.38	0.570 bc	26.96	0.422 cd	17.58	0.398 b	16.05
Resident annuals	0.559 ab	26.26	0.535 c	24.74	0.382 d	15.04	0.424 b	17.70
Open (no vegetation)	0.564 ab	26.58	0.628 a	30.64	0.647 a	31.85	0.649 a	31.97
Site 2 average	0.566 A	26.71	0.596 A	28.61	0.489 B	21.83	0.466 B	20.37
Sd, 24 d.f.	0.025		0.023		0.040		0.042	

* Within depth and site, species count ratio means with the same lower letter are not significantly different at P < 0.10.

** Within depth, site count ratio means with the same upper case letter are not significantly different at P < 0.10.

season rather than infiltration during the current season.

B. Winter Growth Period

The 1988-89 winter growth period was an exceptionally cold one. Plant growth in general was slower at Site 2 than at Site 1 during the winter period (Chapter I.B.2). Subplot soil moisture contents were not different by the end of the winter growth period. Thus, competition had not yet been a factor with respect to soil moisture levels.

Soil moisture content was higher at Site 2 than at Site 1 at all depths by the end of the winter growth period (Table II.4). The site difference may have been a function of one or both of two possibilities. First, as mentioned above, plant growth was slower at Site 2 than at Site 1 during this period. Second, the Carney clay soils at Site 2 may have a higher water holding capacity than the Darrow silty clay loams at Site 1. Sampling at 15 cm on March 16, 1989 when soils were close to if not at field capacity indicated percent volumetric soil moisture levels of 37.3 and 30.2 at Sites 2 and 1, respectively.

Site 1 soil moisture differences by species at 15 cm (Table II.4) reflected differential growth from mid-March through April 5, 1989 (unpublished data). During that period, plots of the wheatgrasses and of the resident annuals had higher growth rates and greater soil moisture withdrawl than Idaho fescue or the orchardgrasses.

Table II.4. Winter - early spring transition (April 5, 1989) site by species neutron probe mean count ratios (measure count/standard count) comparison within depth. % vol. is percent volumetric soil moisture as calculated from the count ratio.

Species	15 cm		30 cm		45 cm		60 cm	
	Count ratio	% vol.	Count ratio	% vol.	Count ratio	% vol.	Count ratio	% vol.
(Site 1)								
Idaho fescue	0.611 a *	29.56	0.653 a	32.23	0.665 a	32.99	0.680 a	33.94
Berber orchardgrass	0.603 a	29.06	0.656 a	32.42	0.671 a	33.37	0.674 a	33.56
Palestine orchardgrass	0.603 a	29.06	0.652 a	32.16	0.668 a	33.18	0.675 a	33.62
Tall wheatgrass	0.592 ab	28.36	0.639 a	31.34	0.661 a	32.73	0.676 a	33.68
Intermediate wheatgrass	0.601 b	28.93	0.642 a	31.53	0.659 a	32.61	0.677 a	33.75
Resident annuals	0.556 c	26.07	0.635 a	31.08	0.645 a	31.72	0.670 a	33.30
Open (no vegetation)	0.614 a	29.75	0.652 a	32.16	0.665 a	32.99	0.679 a	33.88
Site 1 average	0.597 B **	28.67	0.648 B	31.91	0.663 B	32.86	0.676 B	33.68
(Site 2)								
Idaho fescue	0.654 a	32.29	0.699 a	35.14	0.704 ab	35.46	0.703 ab	35.40
Berber orchardgrass	0.647 a	31.85	0.693 ab	34.76	0.706 a	35.59	0.689 c	34.51
Palestine orchardgrass	0.645 a	31.72	0.705 a	35.52	0.705 a	35.52	0.708 a	35.71
Tall wheatgrass	0.652 a	32.16	0.699 a	35.14	0.717 a	36.29	0.706 a	35.59
Intermediate wheatgrass	0.630 a	30.77	0.698 a	35.08	0.706 a	35.59	0.690 bc	34.57
Resident annuals	0.619 a	30.07	0.658 c	32.54	0.698 ab	35.08	0.690 bc	34.57
Open (no vegetation)	0.631 a	30.83	0.674 bc	33.56	0.686 b	34.32	0.683 c	34.13
Site 2 average	0.640 A	31.40	0.689 A	34.51	0.703 A	35.40	0.698 A	35.08
Sd, 24 d.f.	0.021		0.012		0.011		0.010	

* Within depth and site, species count ratio means with the same lower case letter are not significantly different at $P < 0.10$.

** Within depth, site count ratio means with the same upper case letter are not significantly different at $P < 0.10$.

There were no plot differences among the species at 30, 45 or 60 cm at Site 1. At Site 2, there were differences (Table II.4) which may have reflected differential growth rates among the species with a consequent effect on transpiration and thus indirectly on infiltration. Lower soil moisture levels under the resident annuals at 30 cm may have reflected the higher growth rate they experienced relative to the perennial grasses during the end of the winter period. There were no differences among the plots with vegetation at 45 cm. Infiltration during the cold period when nothing was actively growing may have leveled out the soil moisture content at 45 cm prior to resumption of growth during the late winter period. At 60 cm, plots of Berber orchardgrass, the resident annuals and, to a lesser extent, Idaho fescue had lower moisture levels than the others. Fall and early winter growth activity among those species may have withdrawn enough moisture during active growth to reduce the amount available for infiltration.

At Site 2, soil moisture content under the Open plots tended to be lower at 30, 45 and 60 cm than under the perennial grass plots. Soil structure improvement from perennial grass roots may have accounted for the trend. Root development, particularly under plants that had not yet actively grown in 1989, could have aided infiltration.

Soil moisture levels on April 5, 1989 probably reflected near field capacity for these sites. Plots in which plants had been actively growing were probably somewhat below field capacity. However, those plots in which there had been little or no growth activity were probably at field capacity. Results from field capacity determinations made in the laboratory were too uncertain to provide reliable estimates of field capacity for these soils.

C. Early Spring Growth Period

During the two weeks of the early spring growth period (April 5-15, 1989), sub-subplot differences [species by status (vispore covered vs uncovered) interaction effect] became significant ($P < 0.10$) at 15, 30 and 45 cm. Vispore covered sub-subplots (no competition, mulch effect) had higher soil moisture levels at all three depths for the two wheatgrasses, and at 15 and 30 cm for Palestine orchardgrass (Table II.5). Differences were not significant among Idaho fescue, Berber orchardgrass or the Open plots. These results corresponded with the degree of reinvasion among the plots by resident annuals as reflected by resident annual dry matter biomass and cover differences among the plots (Chapter III). Idaho fescue and Berber orchardgrass had less weed growth than did the others and thus less weed induced soil moisture withdrawl. The lack of difference in the Open plots indicated little

Table II.5. Early spring (5-15 April 1989) species by status [competition (C) vs no competition (NC)] interaction of neutron probe count ratios (measure count/standard count) within depth. % vol. is percent volumetric soil moisture as calculated from the count ratio.

	15 cm				30 cm			
	C		NC		C		NC	
Species	Count ratio	% vol.	Count ratio	% vol.	Count ratio	% vol.	Count ratio	% vol.
Idaho fescue	0.502 a *	22.65	0.504 a	22.78	0.623 a	30.32	0.620 a	30.13
Berber orchardgrass	0.478 a	21.13	0.505 a	22.84	0.607 b	29.31	0.622 a	30.26
Palestine orchardgrass	0.507 b	22.97	0.537 a	24.87	0.617 b	29.94	0.635 a	31.08
Tall wheatgrass	0.486 b	21.63	0.537 a	24.87	0.589 b	28.17	0.620 a	30.13
Intermediate wheatgrass	0.461 b	20.05	0.537 a	24.87	0.584 b	27.85	0.631 a	30.83
Resident annuals only	0.506	22.90	N/A	N/A	0.581	27.66	N/A	N/A
No vegetation	0.602 a	28.99	0.578 a	27.47	0.651 a	32.10	0.652 a	32.16

	45 cm				60 cm			
	C		NC		C		NC	
Species	Count ratio	% vol.	Count ratio	% vol.	Count ratio	% vol.	Count ratio	% vol.
Idaho fescue	0.648 a	31.91	0.654 a	32.29	0.670 a	33.30	0.678 a	33.81
Berber orchardgrass	0.656 a	32.42	0.662 a	32.80	0.669 a	33.24	0.670 a	33.30
Palestine orchardgrass	0.657 a	32.48	0.663 a	32.86	0.673 a	33.49	0.676 a	33.68
Tall wheatgrass	0.635 b	31.08	0.649 a	31.97	0.659 a	32.61	0.655 a	32.35
Intermediate wheatgrass	0.633 b	30.96	0.661 a	32.73	0.650 b	32.04	0.669 a	33.24
Resident annuals only	0.638	31.27	N/A	N/A	0.648	31.91	N/A	N/A
No vegetation	0.664 a	32.92	0.667 a	33.11	0.665 b	32.99	0.681 a	34.00

* Within depth and species, count ratio means with the same letter are not significantly different at $P < 0.10$ with respect to competition vs no competition.

evaporative loss during the early spring period.

The site by species interaction effects for soil moisture were significant ($P < 0.01$) at 30 and 45 cm, but were not significant ($P > 0.10$) at 15 or 60 cm. Site and species main effects were significant ($P < 0.01$) at all four depths.

Repeated measures ANOVA indicated significant differences for both site and species main effects between April 5 and April 15, 1989 at all four depths. Soil moisture levels within Site 1 were noticeably lower at all four depths with the major changes at 15 and 30 cm (Tables II. 4 and 6). Within Site 2, soil moisture levels were noticeably lower at 15 cm. Reductions were apparent at 30 and 45 cm, but not to the extent observed at Site 1 (Tables II. 4 and 6). Differences between April 5 and April 15 at site 2 were negligible at the 60 cm depth. Among the perennial grasses, growth rates were generally higher at Site 1 than at Site 2 during the early spring period which may have accounted for the site differences. A higher water holding capacity by the clay soil at Site 2 relative to the silty clay loam soil at Site 1 may also have been a factor. Since the soils were still relatively wet during this period, possible differences in matric potential probably did not contribute to the site differences at 45 and 60 cm depths.

Table II.6. Early spring to spring transition (April 15, 1989) site by species neutron probe mean count ratio (measure count/standard count) comparison within depth. % vol. is percent volumetric soil moisture as calculated from the count ratio.

	15 cm		30 cm		45 cm		60 cm	
Species	Count ratio	% vol.	Count ratio	% vol.	Count ratio	% vol.	Count ratio	% vol.
(Site 1)								
Idaho fescue	0.463 b *	20.18	0.577 b	27.41	0.617 bc	29.94	0.653 a	32.23
Berber orchardgrass	0.455 b	19.67	0.583 b	27.79	0.628 b	30.64	0.655 a	32.35
Palestine orchardgrass	0.473 b	20.81	0.588 b	28.10	0.632 b	30.89	0.652 a	32.16
Tall wheatgrass	0.486 b	21.63	0.573 b	27.15	0.610 c	29.50	0.638 b	31.27
Intermediate wheatgrass	0.475 b	20.94	0.576 b	27.34	0.615 c	29.82	0.641 b	31.47
Resident annuals	0.405 c	16.50	0.567 b	26.77	0.619 bc	30.07	0.634 b	31.02
Open (no vegetation)	0.574 a	27.22	0.630 a	30.77	0.648 a	31.91	0.660 a	32.67
Site 1 average	0.476 B **	21.00	0.585 B	27.91	0.625 B	30.45	0.649 B	31.97
(Site 2)								
Idaho fescue	0.554 b	25.95	0.671 a	33.37	0.687 a	34.38	0.704 a	35.46
Berber orchardgrass	0.528 bc	24.30	0.648 b	31.91	0.689 a	34.51	0.684 bc	34.19
Palestine orchardgrass	0.571 b	27.03	0.664 ab	32.92	0.690 a	34.57	0.697 ab	35.02
Tall wheatgrass	0.557 b	26.14	0.655 ab	32.35	0.686 a	34.32	0.692 b	34.70
Intermediate wheatgrass	0.557 b	26.14	0.661 ab	32.73	0.692 a	34.70	0.673 cd	33.49
Resident annuals	0.502 c	22.65	0.595 c	28.55	0.657 b	32.48	0.662 d	32.80
Open (no vegetation)	0.606 a	29.25	0.673 ab	33.49	0.683 a	34.13	0.687 b	34.38
Site 2 average	0.553 A	25.88	0.652 A	32.16	0.683 A	34.13	0.686 A	34.32
Sd, 24 d.f.	0.027		0.015		0.009		0.011	

* Within depth and site, species count ratio means with the same lower case letter are not significantly different at $P < 0.10$.

** Within depth, site count ratio means with the same upper case letter are not significantly different at $P < 0.10$.

Early spring growth period significant species differences were primarily a function of less moisture loss in the Open plots and more moisture loss under the resident annuals than occurred among the perennial grass plots (Table II.6). An acceleration of wheatgrass growth rates relative to Idaho fescue and the orchardgrasses began in mid-March and corresponded with less moisture at the 45 and 60 cm depths at Site 1. At Site 2, there were no readily apparent trends among the perennial grasses relative to each other with respect to soil moisture extraction by the end of the early spring period (Table II.6).

D. Spring Growth Period

By the end of the 1988 spring growth period, sub-subplot differences were significant ($P < 0.10$). Neither site by competition nor species by competition interaction effects were significant. Therefore, at both sites and across all species (excluding Open plots), soil moisture levels under the vispore covered sub-subplots (no competition, mulch effect) were significantly higher than those under the sub-subplots subject to competition (i.e. no vispore) (Table II.7). Differences between covered and uncovered sub-subplots in the Open plots were not significant at any depth. Total (resident annual plus perennial grass) production in the uncovered sub-subplots averaged 2985 kg/ha and perennial grass production in the covered sub-subplots averaged 3400 kg/ha. It can be

Table II.7. Spring to summer (May 20, 1988) transition neutron probe count ratio (measure count/standard count) status [competition (C) vs no competition (NC)] comparisons within depth. % vol. is percent volumetric soil moisture as calculated from the count ratio.

	15 cm		30 cm		45 cm		60 cm	
Status	Count ratio	% vol.	Count ratio	% vol.	Count ratio	% vol.	Count ratio	% vol.
C	0.385 b *	15.23	0.461 b	20.05	0.490 b	21.89	0.503 b	22.71
NC (vispour)	0.419 a	17.39	0.490 a	21.89	0.519 a	23.73	0.531 a	24.49

* Differences were significant ($P < 0.10$) at each depth.

concluded that the resident annuals accounted for the additional moisture depletion that occured in those sub-subplots. Therefore, the resident annuals used more water to produce a given amount of above ground biomass.

Site by species interaction effects were significant ($P < 0.10$) at the 30 and 60 cm depths but not at the 15 and 45 cm depths. Site differences were significant at all depths if the Open plots were not included in the analyses.

By the end of the spring growth period, Site 2 had significantly lower moisture levels than did Site 1 at all four depths (Table II.8). However, soil moisture levels in the Open plots were higher at Site 2 than at Site 1 at all depths. Therefore, soil moisture depletion by vegetation at Site 2 was significantly greater than at Site 1. These results corresponded to the higher growth rates observed at Site 2 relative to Site 1 during the spring 1988 growth period (Chapter I.B.4).

Soil moisture level differences among species at 15 cm (Table II.8) corresponded to differences in growth rates experienced during the spring growth period. The resident annuals and the orchardgrasses had the highest growth rates during that period (Chapter I.B.5) which was generally reflected by differences in 15 cm soil moisture levels. The exception was Idaho fescue which had the highest growth rate among the perennial grasses but soil moisture levels which were not different than the wheatgrasses which had

Table II.8. Spring to summer transition (May 20, 1988) site by species neutron probe mean count ratios (measure count/standard count) comparison within depth. % vol. is percent volumetric soil moisture as calculated from the count ratio.

	15 cm		30 cm		45 cm		60 cm	
Species	Count ratio	% vol.	Count ratio	% vol.	Count ratio	% vol.	Count ratio	% vol.
(Site 1)								
Idaho fescue	0.419 b *	17.39	0.468 b	20.49	0.504 b	22.78	0.543 b	25.25
Berber orchardgrass	0.403 b	16.37	0.475 b	20.94	0.506 b	22.90	0.535 bc	24.74
Palestine orchardgrass	0.377 c	14.72	0.447 b	19.16	0.495 bc	22.21	0.524 bcd	24.04
Tall wheatgrass	0.414 b	17.07	0.450 b	19.35	0.472 cd	20.75	0.496 d	22.27
Intermediate wheatgrass	0.388 b	15.42	0.455 b	19.67	0.480 cd	21.25	0.506 cd	22.90
Resident annuals	0.327 d	11.55	0.440 b	18.72	0.465 d	20.30	0.498 d	22.40
Open (no vegetation)	0.559 a	26.26	0.626 a	30.51	0.640 a	31.40	0.648 a	31.91
Site 1 average	0.412 A **	16.94	0.480 A	21.25	0.509 A	23.09	0.536 A	24.81
(Site 2)								
Idaho fescue	0.359 b	13.58	0.441 b	18.78	0.465 b	20.30	0.476 b	21.00
Berber orchardgrass	0.333 c	11.93	0.435 b	18.40	0.475 b	20.94	0.488 b	21.76
Palestine orchardgrass	0.316 c	10.85	0.412 b	16.94	0.455 bc	19.67	0.469 bc	20.56
Tall wheatgrass	0.381 b	14.98	0.439 b	18.65	0.462 b	20.11	0.446 c	19.10
Intermediate wheatgrass	0.347 b	12.82	0.441 b	18.78	0.473 b	20.81	0.469 bc	20.56
Resident annuals	0.298 c	9.71	0.410 b	16.81	0.434 c	18.34	0.437 c	18.53
Open (no vegetation)	0.604 a	29.12	0.656 a	32.42	0.665 a	32.99	0.669 a	33.24
Site 2 average	0.376 B	14.66	0.462 B	20.11	0.490 B	21.89	0.493 B	22.08
Sd, 24 d.f.	0.024		0.024		0.025		0.019	

* Within depth and site, species count ratio means with the same lower case letter are not significantly different at $P < 0.10$.

** Within depth, site count ratio means with the same upper case letter are not significantly different at $P < 0.10$.

the slowest growth rates of the period. Idaho fescue probably required less water per unit of aboveground biomass production than either the introduced grasses or the resident annuals.

Soil moisture content differences at 45 cm at Site 1 and at 60 cm at both sites may have reflected growth rates during the early spring growth period (Chapter I.B.3). During that period, the wheatgrasses and resident annuals had higher growth rates than the orchardgrasses. Higher transpiration rates as a function of higher growth rates at that earlier period may have slowed infiltration by reducing the amount of soil moisture available. The effect would have been lower soil moisture contents at the lower depths by the end of the spring growth period.

Differences in soil moisture contents between the vegetated plots and the Open plots indicated that by the end of the spring growth period, plant growth had impacted soil moisture availability to 60 cm either directly throughactive withdrawl or indirectly through lower infiltration rates.

E. Summer Growth Period

The summer growth periods in both 1987 and 1988 were affected by late season precipitation. An early July 1987 rain impacted both plant growth through the remainder of the season and end of season soil moisture contents. An early June 1988 rain resulted in soil moisture recharge and continued plant growth and development.

Summer 1987 was the end of the first growing season for the transplanted perennial grasses. Idaho fescue had been transplanted as mature plants during the fall while the introduced grasses had been transplanted as seedlings in late winter. Site 2 residual soil moisture contents at the end of the growing season reflected the differences in maturity and in time of transplantation (Table II.9). The relatively low soil moisture residual under Idaho fescue at 60 cm at Site 2 was probably a function of greater initial root biomass and a longer growing season in which to accumulate additional root biomass than was possible for the other perennial grasses. That the difference was not greater and that there was essentially no difference at Site 1 may have indicated a greater water use efficiency by Idaho fescue relative to the others.

An interesting result in 1987 was the difference between the California oatgrass (Danthonia californica) plots and the others, particularly the resident annuals, with respect to residual soil moisture. Because of the sod forming nature of California oatgrass, it did not respond well to small clump transplantation. The result was complete dominance of the plots by the annual grass dogtail (Cynosurus echinatus). By the end of the season, residual soil moisture was greater under the dogtail plots than under any of the other vegetated plots. Dogtail was

Table II.9. End of season (August 24, 1987) site by species neutron probe mean count ratios (measure count/standard count) comparison within depth. Perennial grass plots were all covered with vispour to prevent competition from the resident annuals; therefore, there was no competition vs no competition comparison for 1987. % vol. is percent volumetric soil moisture as calculated from the count ratio.

	15 cm		30 cm		60 cm	
Species	Count ratio	% vol.	Count ratio	% vol.	Count ratio	% vol.
(Site 1)						
Idaho fescue	0.304 c *	10.09	0.419 c	17.39	0.536 c	24.81
Berber orchardgrass	0.313 c	10.66	0.436 c	18.46	0.535 c	24.74
Palestine orchardgrass	0.292 c	9.33	0.410 c	16.81	0.534 c	24.68
California oatgrass	0.396 b	15.93	0.513 b	23.35	0.586 b	27.98
Resident annuals	0.280 c	8.57	0.416 c	17.20	0.463 d	20.18
Open (no vegetation)	0.518 a	23.66	0.620 a	30.13	0.655 a	32.35
Site 1 average	0.357 A **	13.45	0.474 A	20.87	0.560 A	26.33
(Site 2)						
Idaho fescue	0.300 c	9.84	0.402 b	16.31	0.465 cd	20.30
Berber orchardgrass	0.260 c	7.30	0.397 bc	15.99	0.503 bcd	22.71
Palestine orchardgrass	0.245 c	6.35	0.356 c	13.39	0.506 bc	22.90
California oatgrass	0.395 b	15.86	0.428 b	17.96	0.523 b	23.98
Resident annuals	0.259 c	7.24	0.338 c	12.25	0.458 d	19.86
Open (no vegetation)	0.570 a	26.96	0.645 a	31.72	0.657 a	32.48
Site 2 average	0.345 A	12.69	0.436 B	18.46	0.524 B	24.04
Sd, 24 d.f.	0.034		0.033		0.028	

* Within depth and site, species count ratio means with the same lower case letter are not significantly different at $P < 0.10$.

** Within depth, site count ratio means with the same upper case letter are not significantly different at $P < 0.10$.

nearing maturity when the early July rains arrived. Dogtail plants were not able to effectively utilize the additional late moisture while the perennial grasses and yellow starthistle (Centaurea solstitialis) in other plots were able to capitalize on it and continue growth.

By the end of the 1988 growing season, soil moisture residual differences among plots of the various species were generally insignificant (Table II.10). At 15 cm, soil moisture under resident annuals tended to be slightly lower than under the perennial grasses. Differences among the perennial grasses at 15 cm were not significant at Site 1. At Site 2, with the exception of Idaho fescue, the small differences that did appear reflected peak standing crop differences (Chapter I.A). Tall wheatgrass had both the lowest peak standing crop and the highest residual soil moisture content. Below 15 cm, species differences were not significant. At both sites, residual annuals left the least amount of soil moisture at 15 cm. Although Idaho fescue had by far the highest peak standing crop at Site 2, residual soil moisture was not different relative to the other perennial grasses. The implication was more effective use of the water by Idaho fescue.

Site differences and Open plots differences provided interesting results (Table II.10). Lack of site differences at 45 and 60 cm were largely a function of the differences in moisture levels in the Open plots. When the

Table II.10. End of season (August 6, 1988) site by species neutron probe mean count ratios (measure count/standard count) comparison within depth. % vol. is percent volumetric soil moisture as calculated from the count ratio.

	15 cm		30 cm		45 cm		60 cm	
Species	Count ratio	% vol.	Count ratio	% vol.	Count ratio	% vol.	Count ratio	% vol.
(Site 1)								
Idaho fescue	0.282 b *	8.70	0.387 b	15.36	0.417 b	17.26	0.453 b	19.54
Berber orchardgrass	0.282 b	8.70	0.399 b	16.12	0.433 b	18.27	0.462 b	20.11
Palestine orchardgrass	0.275 b	8.25	0.384 b	15.17	0.432 b	18.21	0.467 b	20.43
Tall wheatgrass	0.274 b	8.19	0.389 b	15.48	0.428 b	17.96	0.457 b	19.80
Intermediate wheatgrass	0.258 b	7.17	0.387 b	15.36	0.424 b	17.70	0.454 b	19.61
Resident annuals	0.192 c	2.99	0.363 b	13.83	0.426 b	17.83	0.450 b	19.35
Open (no vegetation)	0.402 a	16.31	0.551 a	25.76	0.557 a	26.14	0.573 a	27.15
Site 1 average	0.281 A **	8.63	0.409 A	16.75	0.445 A	19.03	0.474 A	20.87
(Site 2)								
Idaho fescue	0.268 b	7.81	0.370 b	14.28	0.404 b	16.43	0.429 b	18.02
Berber orchardgrass	0.223 bc	4.96	0.345 bc	12.69	0.407 b	16.62	0.458 b	19.86
Palestine orchardgrass	0.210 bc	4.13	0.315 bc	10.79	0.377 b	14.72	0.432 b	18.21
Tall wheatgrass	0.234 b	5.65	0.357 bc	13.45	0.407 b	16.62	0.428 b	17.96
Intermediate wheatgrass	0.196 c	3.24	0.303 bc	10.03	0.383 b	15.10	0.432 b	18.21
Resident annuals	0.170 c	1.59	0.284 c	8.82	0.399 b	16.12	0.448 b	19.22
Open (no vegetation)	0.418 a	17.32	0.599 a	28.80	0.634 a	31.02	0.644 a	31.66
Site 2 average	0.247 B	6.48	0.368 B	14.15	0.429 A	18.02	0.467 A	20.43
Sd, 24 d.f.	0.024		0.024		0.025		0.019	

* Within depth and site, species count ratio means with the same lower case letter are not significantly different at P < 0.10.

** Within depth, site count ratio means with the same upper case letter are not significantly different at P < 0.10.

Open plots were excluded from the analyses, the 45 cm Site 1 and Site 2 count ratio means were .426 and .396, and the 60 cm count ratio means were .458 and .437, respectively, and site differences at both depths were significant at $P < 0.10$. While Site 1 had consistently higher residual moisture in the vegetated plots, Site 2 had consistently higher residual moisture in the Open plots. The implication was that while Site 2 clay soils had a greater moisture holding capacity and probably a greater matric potential than Site 1 silty clay loam soils, vegetation during the spring flush of growth was able to extract more moisture from Site 2 soils than from Site 1 soils. During the late spring and early summer of 1988, perennial grasses at Site 2 had considerably higher growth rates than they had at Site 1 (Chapter I). A possible explanation for the accelerated growth rates at Site 2 relative to Site 1 has been provided in the conclusion section of Chapter 1.

F. Summary of Points of Interest from Results

Soil moisture changes through the growing season were a function of both plant growth and physical soil characteristics. Water movement through Site 2 heavy clay soils was slower than through Site 1 silty clay loam soils. During the fall and winter recharge periods, moisture recharge at 45 and 60 cm depths was slower at Site 2 than at Site 1 despite essentially the same amount of precipitation at both sites and generally slower plant growth, and thus less water use, at Site 2.

Water holding capacity and water retention at Site 2 was greater than at Site 1. Percent volumetric soil moisture at or near field capacity in March 1989 was higher at Site 2 than at Site 1 (37.3% and 30.2% at Sites 2 and 1, respectively). End of season 1988 soil moisture contents under the Open (no vegetation) plots were higher at all depths at Site 2 relative to Site 1. These results indicated both greater water holding capacity and greater water retention capacity (matric potential) at Site 2 relative to Site 1.

Plant growth affected soil moisture both directly and immediately through active water withdrawl (i.e. transpiration) and indirectly after some delay through reduced infiltration because of less available moisture. These effects were moderated somewhat by apparent differences in the amount of water used by the various species (e.g. higher growth rates and total production at Site 2 by Idaho fescue was not reflected by lower soil moisture contents relative to the other species). When species growth rates were different during periods when precipitation events were frequent, the differences in plant growth were not reflected initially by near surface soil moisture contents. However, the differences did appear later in the form of lower moisture contents at greater depth as a result of less moisture available for infiltration. This situation apparently occurred at Site 2 by the end of the winter 1989 growth period. At that time, plots with Berber orchardgrass, the resident annuals, and to a lesser extent, Idaho fescue plots had lower moisture contents at 60 cm than did the others. Fall and early winter growth activity among those species may have withdrawn enough moisture during active growth to sufficiently reduce the amount of water available for infiltration.

When differential plant growth occurred during periods with little or no precipitation, differences were apparent among the plots of the various species in the form of different surface soil moisture contents. Again, by the end of the winter 1989 growth period, soil moisture differences among plots at 15 cm depth reflected differential plant growth from mid-March through April 5, 1989. During that period, the wheatgrasses and resident annuals had higher growth rates and lower residual soil moisture levels at 15 cm than Idaho fescue or the orchardgrasses.

Competition from the resident annuals was apparent during the early spring 1989 and spring 1988 growth periods. By the end of the early spring 1989 period, the two wheatgrasses and Palestine orchardgrass had significantly less soil moisture to 45 cm in the uncovered sub-subplots subject to competition from resident annuals than was present under the vispore covered sub-subplots. Differences between the covered and uncovered sub-subplots were not apparent in the Idaho fescue, Berber orchardgrass or Open (no vegetation) plots. Idaho fescue and Berber orchardgrass subplots had less resident annual reinvasion than did the wheatgrasses or Palestine orchardgrass. By the end of the spring 1988 growth period, soil moisture contents under the vispore covered sub-subplots were significantly higher than under the uncovered sub-subplots with the exception of the Open plots. Total weed plus perennial grass biomass in the uncovered sub-subplots was less than perennial grasses alone in the covered sub-subplots. The implication was much greater extraction of water per unit of aboveground biomass produced by the annual weeds which were dominated by forbs.

Conclusions

Results from this study have shown that soil moisture content alone is not the best way to compare growth patterns or potentials of various plant species if they are active during the same general time periods and at the same soil depths. If plant growth occurs during periods when precipitation is frequent, soil moisture recharge can obscure moisture withdrawl by the active species. Differences in water use efficiencies among species also tend to obscure differences in growth patterns. However, soil moisture monitoring with a neutron probe was effective in verifying growth analysis results. Differences in soil moisture contents at the 45 and 60 cm depths corresponded to earlier differences in species' growth rates. Those species such as Berber orchardgrass, Idaho fescue and the resident annuals that had been active in the fall had lower soil moisture contents at 45 and 60 cm by the end of winter than did the wheatgrasses which had not been active during the fall. Based on soil moisture contents, it was possible to identify the earlier growing species as Berber orchardgrasss, resident annual plants and, to a lesser extent, Palestine orchardgrass. When sampling was done following a long enough dry period, it was possible to identify the differential growth rates that had recently been occurring. For example, the wheatgrasses were active during the latter half of March 1989 while the orchardgrasses had been relatively inactive and the differences were reflected by the residual surface moisture levels. Active growth periods of Idaho fescue were more difficult to determine because of water use relative to the others.

The objective of examining the timing of soil moisture extraction by selected perennial grasses and the resident annual community through their periods of active growth was met with marginal success through use of a neutron probe. When combined with knowledge of growth analysis results, neutron probe results were interpretable and were useful in verifying growth analysis results. These results were also useful in helping to identify the relatively high water use efficiency of Idaho fescue and the relatively low water use efficiency of the resident annual weeds which were dominated by forbs, particularly yellow starthistle.

The second objective of this portion of the study was to compare the end of season extent of soil moisture extraction. That objective was met. Residual end of season soil moisture levels were generally not differenct among the perennial grasses. Moisture contents were not much different when perennial grasses were compared to the resident annuals dominated by forbs which included the late growing yellow starthistle. However, the resident annual grasses which were represented in the California oatgrass plots left considerably more residual moisture than did the perennial grasses or the annual forb dominated plots.

Several additional implications were apparent from this study:

1) Following a dry winter, appreciable soil moisture recharge may not occur below 30 - 45 cm because growing plants would be using available moisture near the surface and consequently less moisture is available to infiltrate lower depths. In such years, the earlier growing plants such as the resident annuals, Idaho fescue and Berber orchardgrass should have an advantage over later growing plants such as the wheatgrasses. Since most available

water for plant growth would be near the surface in such a year, the perennial grasses would have to be effective in retarding reinvasion by the less water use efficient annuals to have sufficient moisture for growth to maturity and maintenance of a vigorous, long-lasting stand.

2) This study provided an indirect inference of soil structure improvement by the perennial grasses. Downward movement of soil moisture was more rapid under the perennial grass plots than under the Open (no vegetation) plots at Site 2 (heavy clay soil) during the 1988-89 winter period when little plant growth had occurred. Soil structure improvement from perennial grass roots may have accounted for the trend. Root development, particularly under plants that had not yet actively grown, could have improved soil structure and aided infiltration.

3) A final interesting implication of this study was the apparent effect of differences in growing conditions on the abilities of plants to extract soil moisture. The heavy clay Site 2 soils had a higher water holding capacity than the silty clay loam Site 1 soils, but they also had a greater matric potential and thus a greater resistance to releasing the moisture held. As a result of different growing conditions, plants at Site 2 accelerated growth rates considerably relative to those at Site 1 during the late spring and early summer of 1988. In spite of the soil differences noted above, Site 2 plants were able to extract

moisture to a lower content than were Site 1 plants.

A final personal conclusion is that soil moisture monitoring with a neutron probe is more useful in comparing site potentials than it is in comparing timing of soil moisture extraction within a site by species with relatively similar growth periods and which extract moisture from essentially the same strata.

CHAPTER III

EVALUATION OF PERENNIAL GRASSES FOR RESISTANCE TO REINVASION BY ANNUAL WEEDS

Introduction

Past uses of the foothills pastures and rangelands of southwestern Oregon have resulted in dominance by undesirable annual species. Serious attempts are now being made to restore valuable perennial forage species on these areas by reducing grazing pressure or by artificial seeding. Both of these alternatives are expensive (Harris 1967).

From both forage resource and conservation perspectives, a perennial grass dominant would be much preferable to the resident annual mix. Perennial grasses would be expected to produce a greater amount of available forage for livestock over a longer period of time in the important spring - early summer grazing period. They should also provide a more stable forage base than the extremely variable production exhibited by annuals from one year to the next in a Mediterranean/Maritime climate. This would facilitate planning of grazing management. Through a more extensive and deeper rooting system, adapted perennial grasses should be better than annuals in improving soil structure and in reducing erosion potential. A period of growth extending into summer should result in greater soil moisture depletion and suppression of yellow starthistle.

If perennial grasses did at one time dominate these sites, they have not been able to regain entry other than in limited favorable microsites. It is not known if the absence of perennial species is the result of competition by annual weeds following suppression by overgrazing or if endemic heavy clay soils and climatic conditions largely preclude the establishment of communities of desirable perennial grasses beyond favorable microsites. The limited distribution of native perennial grasses and their virtual exclusion from open sites effectively eliminates grazing management alone as a potential method of improvement within a reasonable period of time. If significant improvement is to be accomplished, a reseeding effort will be required. Before ranchers and other land managers expend additional time and resources in an attempt to find the perennial grass alternatives to be used in a reseeding effort, the potential for establishing and maintaining a perennial grass component should be clarified. Knowing which perennial grasses, once established, are best able to resist reinvasion by the resident annuals would facilitate the search for those to be used in reseeding attempts.

Several studies have concluded that in competition among seedlings, period of active growth is a major determinant of dominance (Harper 1977, Harris 1967, Harris and Wilson 1970, Ross and Harper 1972, Wilson, et.al. 1966). Generally, the individual plants able to germinate and commence growth earliest are able to achieve a significant competitive advantage. The ability to continue growth through the cold period was found to contribute to the competitive advantage of winter annual grasses, cheatgrass (Bromus tectorum) and medusahead (Taeniatherum asperum), over bluebunch wheatgrass (Agropyron spicatum) seedlings (Harris 1967, Harris and Wilson 1970). In contrast, the root tips of crested wheatgrass (A. desertorum) seedlings were able to penetrate the soil almost as rapidly as the two annuals and remain in favorable soil moisture (Harris and Wilson 1970).

Under conditions to which they are adapted, established mature perennial grasses have a natural competitive advantage over annual grasses (Harris 1967, Harris and Wilson 1970) because of prior root development which allows them to maintain contact with available soil moisture (Harris 1977). It is not necessary for them to begin from seed following each dormant period. However, once mature plants are removed, and re-establishment from seed is required, perennials are at a disadvantage.

The above arguments tend to support the "inhibition" model of secondary succession proposed by Connell and Slatyer (1977) which states that all species resist invasion of competitors. The first occupants preempt the space and continue to exclude or inhibit late colonists until the former die or are damaged.

As indicated above, numerous studies have been conducted to determine competitive interactions between perennial and annual grass seedlings (Harris 1967, 1977, Harris and Wilson 1970, Jackson and Roy 1986, Rummell 1946, Young, et.al. 1968 a,b). However, field studies that bypass the seedling establishment phase to determine species' potentials to maintain niche occupancy have not been tried under conditions similar to those in the study area. A primary objective of this study, conducted in the foothills of southwestern Oregon, was to evaluate the abilities of several selected perennial grasses to resist reinvasion by resident annual plants once the perennials had had a reasonable chance to become established.

Materials and Methods

Study Site

The study was conducted at two foothills sites in Jackson County in southwest Oregon. Site 1 (mid slope) is located 3 km east of Phoenix on the Ferns ranch, and Site 2 (toe slope) is located about 5 km northeast of Ashland on the Dauenhauer ranch. Soils at the two sites are Darrow silty clay loam and Carney clay, respectively. The Darrow series consists of moderately well drained soils formed in weathered siltstone or shale bedrock. Permeability is slow. The effective rooting depth is commonly 75 to 100 cm. Shrink-swell potential is moderate in the surface 30 cm and high below 30 cm. The Carney series consists of moderately deep, moderately well drained soils on fans and hillslopes. These soils formed from alluvium and colluvium weathered from Tuffs and Breccias. Typically, these soils are dark brown clay throughout. Permeability is slow. Shrink swell capacity is severe throughout. Sites 1 and 2 have west and southwest aspects, respectively; and slopes are 20-35% (mid slope) and 5-20% (toe slope), respectively. The area is characterized by a Mediterranean/Maritime climate pattern with cool wet winters and hot dry summers. Annual precipitation averages 500 - 600 mm at both sites, but distribution and quantity vary considerably from year to year. On average, approximately 82% of the precipitation falls between October 1 and April 30, 4.8% in May, 2.3% in June and 0.7% in July. The average January temperature is 3.3°C and the average July temperature is 21.1°C. Extreme temperatures range from -20°C to 41°C.

Plant Materials

Eleven species or varieties of species (Table III.1) of perennial grass were evaluated. Three of the species were natives growing in association with oak (*Quercus garryana*) on sites similar to the study sites. The others were introduced species.

Table III.1. Perennial grass species included in the study.

Agropyron elongatum	Tall wheatgrass
A. intermedium	Intermediate wheatgrass
A. varnense	Rush wheatgrass
Dactylis glomerata	
varieties 'Berber'	Berber orchardgrass
'Paiute'	Paiute orchardgrass
'Palestine'	Palestine orchardgrass
Danthonia californica	California oatgrass (native)
Festuca arundinacea	Tall fescue
Festuca idahoensis	Idaho fescue (native)
Koeleria cristata	Junegrass (native)
Lolium perenne	Perennial ryegrass

Southwest Oregon foothills are currently dominated by the annual grasses medusahead (*Taeniatherum asperum*), dogtail (*Cynosurus echinatus*), bulbous bluegrass (*Poa bulbosa*), and ripgut brome (*Bromus rigidus*); and by assorted annual forbs including, during late spring and summer, yellow starthistle (*Centaurea solstitialis*).

Plot Design

All perennial grasses were transplanted into plots during the fall and winter of 1986-87 and allowed to establish in the absence of competition during the 1986-87 growing season. Suppression of competition was accomplished by transplanting into plots covered with black vispour. The vispour had 400 holes per square inch to allow water and air passage. Following establishment during the first growing season, the plots were split by removing the vispour from half of each plot. The resident annuals were thus allowed to reinvade and provide competition for the perennials on half of each plot while the perennials remained competition free on the other half.

Sampling

To avoid destructive harvesting within the plots, the sampling procedure used was the weight estimate technique (Pechanec and Pickford 1937). Fifteen individual subsamples per subplot were obtained to determine a mean for the subplot. Plants on the perimeter of the plots and additional plants transplanted around the perimeter of each site served as calibration plants. Biomass and percent foliar cover of the annual grasses and annual forbs were estimated around each perennial grass plant in the uncovered subplots. Since perennial grass plants were transplanted in a 25 cm grid, sampling for resident annuals around each plant was within a 25 cm by 25 cm square frame with the perennial grass plant in the center.

To assess the abilities of the perennial grasses to suppress resident annual reinvasion, sampling for the 1987-88 growing season was conducted in May and June during what was thought would be the height of the growing season. Beginning with the 1988-89 growing season two changes were made: 1) Sampling was restricted to plots of resident annuals (no perennial grasses) and plots of the following five perennial grasses: a) Idaho fescue, b) Berber orchardgrass, c) Palestine orchardgrass, d) Tall wheatgrass, and e) Intermediate wheatgrass; and, 2) sampling was conducted once a month from mid-December through mid-March to evaluate fall and winter growth then biweekly through mid-April to evaluate early spring growth. Sampling was terminated on April 15, 1989.

Experimental Design and Analysis

The study was replicated at two sites within the Rogue River Valley. The plot layout within each site consisted of three blocks each of which contained randomly assigned perennial grass species and control plots. Comparison of the perennial grasses with respect to resident annual weed reinvasion was accomplished with the following split-plot model:

Source	d.f.
Site	(a-1)
Block (Site)	(b-1)a
Species	(c-1)
Site * Species	(a-1)(c-1)
Species * Block (Site)	(c-1)(b-1)(a)

Each site was analyzed as a whole plot, and each species and control as a subplot within site. Since Block 1 at Site 1 was not necessarily the same as Block 1 at Site 2, block was nested within site (i.e. Block (Site)) for the analysis rather than treated separately. Block (Site) served as the error term for Site. Species * Block (Site) served as the error term for Species and for Site * Species interactions.

To account for auto-correlation of dates of sampling, multivariate ANOVA was first conducted to provide a conservative screen for significant differences. Univariate analysis followed when differences were detected. An F-protected LSD was used following a significant F-ratio of at least the $P \leq 0.10$ level.

Results and Discussion

Results from May and June 1988 are presented in Tables III. 2 and 3. Percent foliar cover and dry matter biomass of the grasses and forbs were combined since the forbs were generally dominant. The only perennial grass species in which annual grasses were a factor was California oatgrass. California oatgrass did not respond well to the transplanting technique used. Although a little oatgrass survived, the plots were dominated by dogtail (*Cynosurus echinatus*). Other than in the California oatgrass plots, the annual grasses had very little impact and it was concluded that results could be presented as combined grasses and forbs.

Although all of the perennial grasses in the study were able to suppress the resident annuals to some extent, results from May and June 1988 indicated major differences in the abilities of the perennial grasses to resist reinvasion. California oatgrass, Junegrass and Perennial ryegrass were consistently the least able to resist reinvasion (Tables III. 2 and 3). Of the wheatgrasses, Rush wheatgrass was generally the least resistant. Of the

Table III.2. May 1988 mean percent foliar cover (percent cover) and dry matter biomass of resident annual plants per perennial grass plant as measured within a 25cm X 25cm quadrat. (dry matter * 160 = kg/ha).

Percent	Dry	
Species	Cover	Matter (g)
(Site 1)		
Tall wheatgrass	12.93 de *	1.41 e
Intermediate wheatgrass	17.47 de	2.01 e
Rush wheatgrass	24.47 de	3.21 d
Berber orchardgrass	9.07 e	1.21 e
Palestine orchardgrass	12.62 de	1.53 e
Paiute orchardgrass	42.20 c	5.85 d
Perennial ryegrass	60.76 b	10.38 bc
Tall fescue	25.96 d	2.96 de
Idaho fescue	25.56 d	3.46 de
Junegrass	55.95 bc	8.30 c
California oatgrass	63.82 b	13.02 b
resident annuals only	93.64 a	17.54 a
Site 1 average	37.04 A **	5.91 A
(Site 2)		
Tall wheatgrass	10.82 e	1.37 fg
Intermediate wheatgrass	12.84 de	4.04 ef
Rush wheatgrass	23.69 c	4.28 ef
Berber orchardgrass	8.29 e	1.21 g
Palestine orchardgrass	8.24 e	1.04 g
Paiute orchardgrass	35.38 bc	7.12 cde
Perennial ryegrass	35.91 bc	7.99 cd
Tall fescue	26.69 bcd	4.90 def
Idaho fescue	2.20 e	0.33 g
Junegrass	42.36 b	9.00 c
California oatgrass	90.76 a	22.95 a
resident annuals only	82.27 a	17.90 b
Site 2 average	32.62 A	6.85 A
S_d, 44 d.f.	9.32	2.11

* Within column and site, species means with the same lower case letter are not significantly different at $P < 0.10$.

** Within column, site averages with the same upper case letter are not significantly different at $P < 0.10$.

Table III.3. June 1988 mean percent foliar cover (percent cover) and dry matter biomass of resident annual plants per perennial grass plant as measured within a 25cm X 25cm quadrat. (dry matter * 160 = kg/ha).

Percent	Dry	
Species	Cover	Matter (g)
(Site 1)		
Tall wheatgrass	4.13 d *	0.66 d
Intermediate wheatgrass	9.64 cd	1.35 cd
Rush wheatgrass	13.69 cd	3.18 cd
Berber orchardgrass	3.91 d	0.60 d
Palestine orchardgrass	5.69 cd	0.97 d
Paiute orchardgrass	20.29 c	3.48 cd
Perennial ryegrass	50.62 b	16.07 ab
Tall fescue	9.58 cd	1.42 cd
Idaho fescue	14.44 c	3.33 cd
Junegrass	46.64 b	8.83 bc
California oatgrass	80.56 a	21.69 a
resident annuals only	78.89 a	15.17 ab
Site 1 average	28.01 A **	6.39 A
(Site 2)		
Tall wheatgrass	6.09 ef	1.47 de
Intermediate wheatgrass	25.31 cd	10.07 c
Rush wheatgrass	16.40 de	6.24 c
Berber orchardgrass	3.13 ef	0.73 e
Palestine orchardgrass	4.78 ef	1.32 de
Paiute orchardgrass	21.58 cd	8.76 cd
Perennial ryegrass	31.13 bc	19.37 a
Tall fescue	21.96 cd	7.19 cde
Idaho fescue	1.53 f	0.30 e
Junegrass	45.04 b	18.22 ab
California oatgrass	81.78 a	22.83 a
resident annuals only	42.74 b	10.66 bc
Site 2 average	25.12 B	8.93 A
S_d, 44 d.f.	9.32	2.11

* Within column and site, species means with the same lower case letter are not significantly different at $P < 0.10$.

** Within column, site averages with the same upper case letter are not significantly different at $P < 0.10$.

three orchardgrasses, Paiute was by far the least resistant. At the other extreme, results varied somewhat between the two sites. At Site 1, although not statistically significantly different from several other perennial grasses, Berber orchardgrass had the least amount of reinvasion in both May and June in terms of both cover and biomass of the annuals present. Palestine orchardgrass, all three wheatgrasses, Idaho fescue and Tall fescue were nearly as effective with little or no statistical differences among them. At Site 2, again not statistically different, Idaho fescue was consistently the most effective in resisting resident annual reinvasion. Berber and Palestine orchardgrasses and Tall wheatgrass were consistently nearly as effective. Intermediate and Rush wheatgrasses and Tall fescue were more variable at Site 2. Based on the May 17, 1988 results when competition was more intense, the perennial grasses would rank from most to least effective at resisting reinvasion by resident annuals as follows: Berber orchardgrass, Palestine orchardgrass, Tall wheatgrass, Idaho fescue, Intermediate wheatgrass, Rush wheatgrass, Tall fescue, Paiute orchardgrass, Perennial ryegrass, Junegrass, and California oatgrass. At Site 1 alone, ranking of the first five species from most to least resistant to reinvasion would be: Berber orchardgrass, Tall wheatgrass, Palestine orchardgrass, Intermediate wheatgrass, and Tall fescue. At

Site 2 alone, ranking of the first five species from most to least effective would be: Idaho fescue, Palestine orchardgrass, Berber orchardgrass, Tall wheatgrass, and Intermediate wheatgrass.

Based on the 1988 results, subsequent sampling was restricted to Berber and Palestine orchardgrasses, Tall and Intermediate wheatgrasses, the native Idaho fescue, and plots with resident annuals only. Results from December 1988 and January 1989 showed very little difference among the perennial grasses in their abilities to suppress resident annuals early in the growing season (Tables III. 4 and 5). In December there were no site differences. January results indicated a site by species interaction. However, the interaction was a result of resident annual biomass production in the plots without perennial grasses. Production was higher at Site 1. Growth began earlier at Site 1 for both resident annuals and for the perennial grasses (Chapter I). Site differences persisted when the "Weed" plots were eliminated from the analyses (0.93 grams vs 0.70 grams per sample at Sites 1 and 2, respectively), however, there were no differences among the perennial grasses within each site (Table III.5).

By March, species differences were beginning to appear (Table III.6). The orchardgrass plots had less resident annual cover and biomass than did the wheatgrasses. Since a site by species interaction effect was not indicated,

Table III.4. December 1988 species main effects mean percent foliar cover (percent cover) and dry matter biomass of resident annuals per perennial grass plant as measured with a 25cm X 25cm quadrat. (dry matter * 160 = kg/ha).

Species	Percent Cover		Dry Matter (g)	
Idaho fescue	31.07	c *	0.70	b
Berber orchardgrass	30.59	c	0.64	b
Palestine orchardgrass	29.57	c	0.66	b
Tall wheatgrass	40.88	bc	0.84	b
Intermediate wheatgrass	48.44	b	1.02	b
resident annuals only	78.90	a	2.88	a

* Within column, species means with the same letter are not significantly different at $P < 0.10$.

Table III.5. January 1989 site by species interaction effects mean percent foliar cover (percent cover) and dry matter biomass of resident annuals per perennial grass plant as measured with a 25cm X 25cm quadrat. (dry matter * 160 = kg/ha).

Species	Percent Cover	Dry Matter (g)
(Site 1)		
Idaho fescue	43.51 b *	0.93 b
Berber orchardgrass	34.80 b	0.85 b
Palestine orchardgrass	33.84 b	0.78 b
Tall wheatgrass	36.22 b	0.78 b
Intermediate wheatgrass	56.20 b	1.30 b
resident annuals only	89.40 a	4.11 a
Site 1 average	49.00 A **	1.46 A
(Site 2)		
Idaho fescue	33.29 b *	0.64 b
Berber orchardgrass	45.53 b	0.76 b
Palestine orchardgrass	39.91 b	0.77 b
Tall wheatgrass	42.38 b	0.63 b
Intermediate wheatgrass	41.87 b	0.71 b
resident annuals only	78.90 a	2.69 a
Site 2 average	46.98 A	1.03 B
S_d, 20 d.f.	13.48	0.32

* Within column and site, species means with the same lower case letter are not significantly different at $P < 0.10$.

** Within column, site averages with the same upper case letter are not significantly different at $P < 0.10$.

Table III.6. March 1989 species main effects mean percent foliar cover (percent cover) and dry matter biomass of resident annuals per perennial grass plant as measured with a 25cm X 25cm quadrat. (dry matter * 160 = kg/ha).

Species	Percent Cover	Dry Matter (g)
Idaho fescue	46.78 bcd *	1.72 bcd
Berber orchardgrass	38.91 d	1.02 d
Palestine orchardgrass	44.69 cd	1.46 cd
Tall wheatgrass	59.27 bc	2.07 bc
Intermediate wheatgrass	60.64 b	2.45 b
resident annuals only	82.17 a	4.89 a
S_d, 20 d.f.	12.63	0.72

* Within column, species means with the same letter are not significantly different at $P < 0.10$.

species differences were the same at both sites. Site differences persisted as a result of differential fall and winter growth. Site 1 had greater annual plant biomass than did Site 2 (Table III.7).

By April 5, growth rates at Site 2 had accelerated (Chapter I) and site differences in resident annual cover and biomass had disappeared. Species differences persisted with slight changes (Table III.8). Berber orchardgrass retained its position as most effective in suppressing annual plant growth. Differences among the other species were not clear.

By April 15, site differences had reappeared and shifted. Resident annual biomass at Site 2 was greater than at Site 1 (Table III.9). Differences at Site 1 were still somewhat obscure, however, a ranking from most to least effective in suppressing resident annuals would be: Berber orchardgrass, Palestine orchardgrass, Tall wheatgrass, Idaho fescue, and Intermediate wheatgrass. Differences at Site 2 were more definite when considered on a dry matter basis with Berber orchardgrass and Idaho fescue clearly more effective at suppressing annuals than the others. A combined site ranking in order of most to least suppressing would be: Berber orchardgrass, Idaho fescue, Palestine orchardgrass, Tall wheatgrass, and Intermediate wheatgrass.

Table III.7. March 1989 site main effects mean percent foliar cover (percent cover) and dry matter biomass of resident annuals per perennial grass plant as measured with a 25cm X 25cm quadrat. (dry matter * 160 = kg/ha).

	Percent Cover	Dry Matter (g)
Site 1	58.52 a *	2.92 a
Site 2	52.31 a	1.62 b

* Within column, site means with the same letter are not significantly different at $P < 0.10$.

Table III.8. April 5, 1989 species main effects mean percent foliar cover (percent cover) and dry matter biomass of resident annuals per perennial grass plant as measured with a 25cm X 25cm quadrat. (dry matter * 160 = kg/ha).

Species	Percent Cover		Dry Matter (g)	
Idaho fescue	59.61	bc *	1.77	bc
Berber orchardgrass	44.24	d	1.04	c
Palestine orchardgrass	52.21	cd	1.89	b
Tall wheatgrass	65.21	bc	2.34	b
Intermediate wheatgrass	69.47	b	2.60	b
resident annuals only	88.82	a	5.19	a
S_d, 20 d.f.	11.91		0.69	

* Within column, species means with the same letter are not significantly different at $P < 0.10$.

Table III.9. April 15, 1989 site by species interaction effects mean percent foliar cover (percent cover) and dry matter biomass of resident annuals per perennial grass plant as measured with a 25cm X 25cm quadrat. (dry matter * 160 = kg/ha).

Species	Percent Cover	Dry Matter (g)
(Site 1)		
Idaho fescue	72.00 ab *	3.64 b
Berber orchardgrass	37.91 d	1.34 c
Palestine orchardgrass	43.62 cd	1.80 bc
Tall wheatgrass	61.53 bc	2.60 bc
Intermediate wheatgrass	73.15 ab	3.42 b
resident annuals only	91.33 a	6.18 a
Site 1 average	63.26 A **	3.16 B
(Site 2)		
Idaho fescue	50.93 bc *	2.52 c
Berber orchardgrass	45.16 c	2.27 c
Palestine orchardgrass	62.73 bc	4.79 b
Tall wheatgrass	65.44 b	5.27 b
Intermediate wheatgrass	64.51 b	5.34 b
resident annuals only	88.58 a	11.09 a
Site 2 average	62.89 A	5.21 A
S_d, 20 d.f.	11.23	1.08

* Within column and site, species means with the same lower case letter are not significantly different at $P < 0.10$.

** Within column, site averages with the same upper case letter are not significantly different at $P < 0.10$.

Conclusions

Although variability in the data was frequently enough to obscure the differences among perennial grasses in terms of their respective abilities to suppress annual plant growth, relative differences can be discerned after two years of study. After the first year of study, several perennial grasses were eliminated from further consideration on the basis of their inabilities to compete effectively with the resident annual species on the two study sites. Of the remaining species the ranking of effectiveness in suppressing the resident annuals tended to correspond to when they were actively growing. Earlier growing perennial grasses such as Berber orchardgrass and Idaho fescue tended to suppress the annuals more effectively than the later growing perennial grasses such as Intermediate and Tall wheatgrasses. An appropriate conclusion might be that of the perennial grasses adapted to these sites, those most closely following the growth patterns of the annuals are the most effective at outcompeting them.

Other portions of the study have shown that Berber orchardgrass and Idaho fescue have been able to maintain more complete and more uniform stands than have the other perennial grasses. Based on results from this portion of the study, it might be concluded that the ability to suppress annuals is necessary for stand maintenance.

SUMMARY AND CONCLUSIONS

The purpose of this chapter is to summarize the various points of interest that have been discussed separately in various chapters of this dissertation. General conclusions based on overall results will be presented.

Summary

1. With late season precipitation, the later growing perennial grasses are capable of outproducing the earlier growing perennial grasses.
2. Since late spring, early summer precipitation is more frequent in the study area than late season precipitation, earlier maturing grasses should generally have an advantage over the later maturing grasses.
3. Site differences are important with respect to production potentials of the vegetation in general. If a site is situated to receive direct sunlight early in the day when temperatures are moderate during the spring and summer, growth potential appears to be greater than if the site is situated to receive a shorter duration of direct sunlight commencing later in the day.
4. Phenological development may progress more rapidly under the longer duration of daily direct sunlight commencing earlier in the day as described in #3 above.
5. The greater perennial grass production potential described in #3 above is at least partially countered by

greater annual forb production, and thus greater potential competitive interference, for the same reasons. Establishment and stand maintenance of perennial grasses may be more difficult to achieve.

6. Perennial grasses capable of initiating growth subsequent to sufficient fall precipitation and of continuing growth through the winter develop a competitive advantage vis-a-vis the resident annuals when compared to perennial grasses that initiate growth later. During the winter growth period, rates of gain on a per day basis are small. However, over several weeks an advantage in terms of accumulated biomass becomes established. In this study those grasses that initiated growth earliest and maintained growth through the winter had the lowest mortality rates and had the most uniform stands midway through the third growing season.

7. Conclusions reached by Jackson and Roy (1986) tended to be substantiated by this study. The earlier and longer period of drought experienced at Site 2 relative to Site 1, may have been at least partially responsible for slower autumn regrowth, lower vigor and higher mortality rates. The earlier growth initiating grasses did not suffer to the same degree as the later growth initiating grasses.

8. Based on the success of Idaho fescue, it can be concluded that native grasses currently growing only in association with oak have the potential to grow in the open

as well if they can become established.

9. Monitoring soil moisture extraction with a neutron probe is not particularly effective by itself as a tool for monitoring growth activity. The neutron probe was an effective tool to help verify growth analysis results.

10. Use of the neutron probe did indicate that Idaho fescue produced greater aboveground biomass per unit of water and that resident annuals produced less aboveground biomass per unit of water than the other species included in the study.

11. Residual end of season soil moisture levels were not different among the perennial grasses. Residual moisture contents were not much different when perennial grasses were compared to the resident annuals dominated by forbs which included the late growing yellow starthistle. However, the resident annual grasses left considerably more residual moisture than did the perennial grasses or the annual forb dominated plots.

12. Following a dry winter, appreciable soil moisture recharge may not occur below 30 - 45 cm. Actively growing plants use the available moisture as it arrives and reduce the amount available for infiltration.

13. Perennial grasses appeared to have improved soil structure through extensive root production. Downward movement of soil moisture was more rapid under the perennial grass plots than under Open (no vegetation)

plots. However, another possibility is that moisture followed channels formed in the clay subsequent to root death.

14. Growing conditions affect the abilities of plants to extract soil moisture. Under temperature and light conditions more favorable to plant growth, plants were able to extract more moisture from a soil (clay) more resistant to releasing moisture than were plants from the same sources growing in a different soil (silty clay loam) at a different site with less favorable temperature and light conditions.

15. Effectiveness of the perennial grasses in suppressing the resident annual plants corresponded to when they were actively growing. Earlier growing perennials tended to more effectively suppress the annuals than did the later growing perennial grasses.

Conclusions

Stand maintenance potential can be fully assessed only after a number of years of evaluation. The ability of a species to maintain a stand will be a function more of the extreme stress years than of the average years or of those years with better than normal precipitation distribution. Based on historical records, the July 1987 precipitation event was an aberation. June precipitation, as in 1988, can not be counted on. It will be the occassional early, severe drought years that will determine which perennial grasses are best suited to the area. Based on this study, it is my opinion that those grasses able to initiate growth earliest, to continue at least some growth through the winter and to mature earliest will be the grasses that maintain long-term production potential. They may not be the grasses that provide the best production potential in an average or good year. In this study, the two grasses that best fit my concept of an ideal perennial grass for southwestern Oregon foothills are the native Idaho fescue and the introduced Berber orchardgrass. Palestine orchardgrass may have good potential, particularly in low average to good precipitation distribution years. The wheatgrasses have high production potential in those above average to good precipitation distribution (i.e. late season) years as was evident in this study, especially 1987. However, in the long run, the earlier growing and maturing Idaho fescue and Berber orchardgrass have the growth characteristics that should enable them to maintain stand maintenance and thus site occupancy.

BIBLIOGRAPHY

Blackman, V.H. 1919. The compound interest law and plant growth. Ann. Bot. 33:353.

Borman, M.M. 1986. End of Tour Report. USAID/TUNIS. 207 pp.

Cable, D.R. 1969. Competition in the semidesert grass-shrub type as influenced by root systems, growth habits, and soil moisture extraction. Ecology 50(1):27-38.

Connell, J.H. and R.O. Slatyer. 1977. Mechanisms of succession in natural communities and their role in community stability and organization. The American Naturalist 111(982):1119-1144.

Cook, C.W. and J. Stubbendieck (eds.). 1986. Range Research: Basic Problems and Techniques. Society for Range Management, Denver, CO.

Davis, S.D. and H.A. Mooney. 1986. Water use patterns of four co-occurring chaparral shrubs. Oecologia 70:172-177.

Eissenstat, D.M. 1986. Belowground Resource Exploitation in Semiarid Plants: A Comparative Study Using Two Tussock Grasses That Differ in Competitive Ability. Ph.D. Diss., Utah State Univ., Logan.

Eissenstat, D.M. and M.M. Caldwell. 1987. Characteristics of successful competitors: an evaluation of potential growth rate in two cold desert tussock grasses. Oecologia 71:167-173.

Evans, G.C. 1972. The Quantitative Analysis of Plant Growth. University of California Press, Berkeley, CA.

Harper, J.L. 1977. Population Biology of Plants. Academic Press. New York.

Harris, G.A. 1967. Some competitive relationships between Agropyron spicatum and Bromus tectorum. Ecological Monographs 37(2):89-111.

Harris, G. 1977. Root phenology as a factor of competition among grass seedlings. J. Range Manage. 30(3):172-177.

Harris, G.A. and A.M. Wilson. 1970. Competition for moisture among seedlings of annual and perennial grasses as influenced by root elongation at low temperature. Ecology 51(3):530-534.

Harris, G.A., and C.J. Goebel. 1976. Factors in plant competition in seeding Pacific Northwest ranges. Washington State Univ. Agr. Exp. Sta. Bull. 820. 21p.

Hess, K. 1984. End of Tour Report. USAID/TUNIS.

Hunt, R. 1982. Plant Growth Curves: A Functional Approach to Plant Growth Analysis. University Park Press, Baltimore, MD.

Jackson, L.E. 1985. Ecological origins of California's mediterranean grasses. J. Biogeogr., 12:349-361.

Jackson, L.E. and J. Roy. 1986. Growth patterns of mediterranean annual and perennial grasses under simulated rainfall regimes of southern France and California. Acta OEcologia OEcol. Plant., Vol. 7(21), n° 2: 191-212.

Johnson, D.E. 1986. End of Tour Report. USAID/TUNIS.

Miller, P.C. 1981. Plant and stand environment. In: Margaris, N.S. and H.A. Mooney (eds.) Components of Productivity of Mediterranean-Climate Regions - Basic and Applied Aspects. Dr. W. Junk Publishers, The Hague.

Pechanec, J.F. and G.D. Pickford. 1937. A weight estimate method for the determination of range or pasture production. J. of the Am. Soc. of Agron. 29:894-904.

Radosevich, S.R. and J.S. Holt. 1984. Weed Ecology: Implications for Vegetation Management. John Wiley & Sons, New York.

Ross, M.A. and J.L. Harper. 1972. Occupation of biological space during seedling establishment. J. of Ecology 60(1):77-88.

Rummell, R.S. 1946. Some effects of competition from cheatgrass brome on Crested wheatgrass and Bluestem wheatgrass. Ecology 27:159-167.

Thorgeirsson, H. 1985. Temporal and spatial partitioning of the soil water resource between two Agropyron bunchgrasses and Artemisia tridentata. M.S. Thesis, Utah State Univ., Logan.

Wilson, A.M., G.A. Harris, and D.H. Gates. 1966. Fertilization of mixed cheatgass - bluebunch wheatgrass stands. J. Range Manage. 19:134-137.

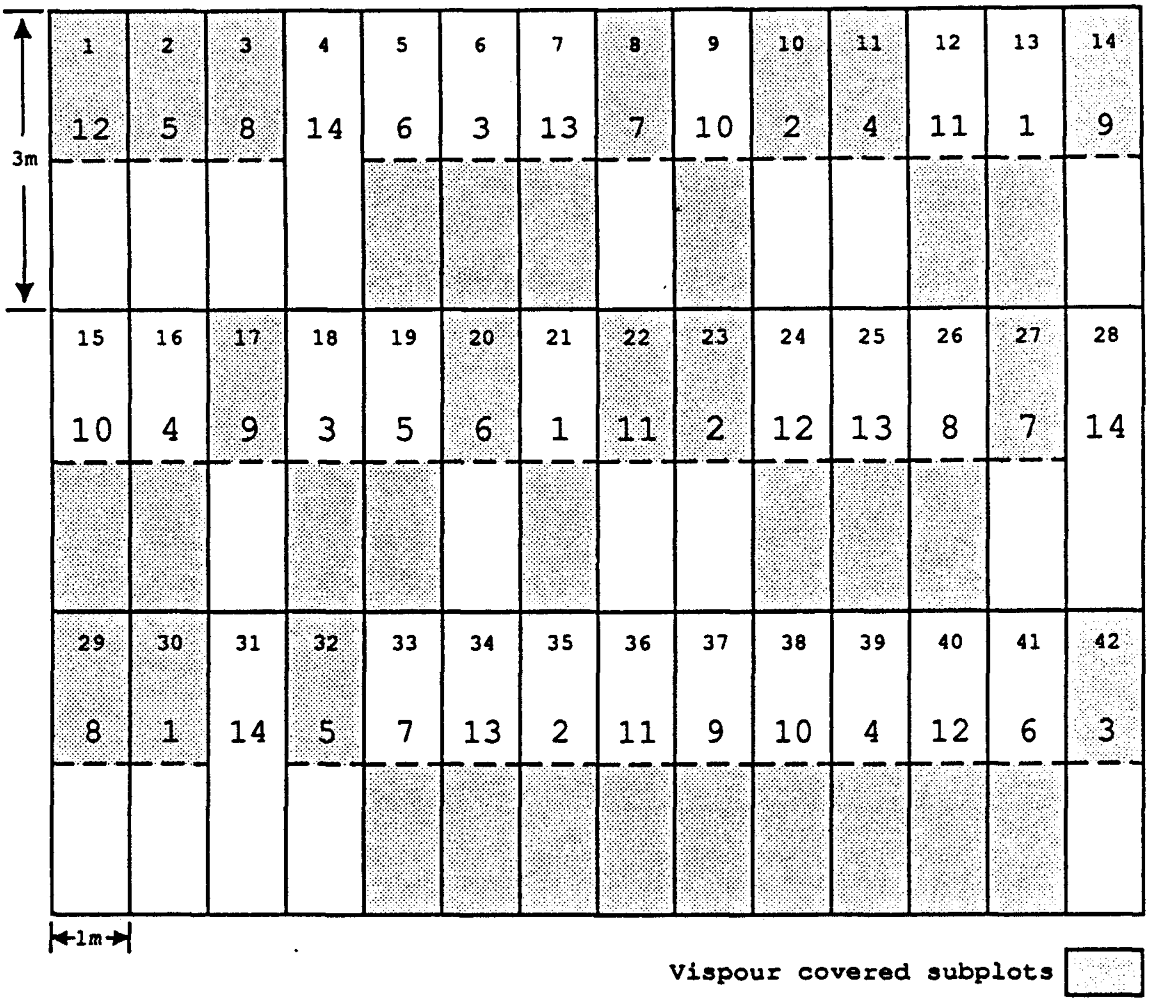
Young, J.A., R.A. Evans, and R.E. Eckert, Jr. 1968(a). Germination of medusahead in response to temperature and afterripeing. Weed Sci. 16:92-95.

Young, J.A., R.A. Evans, and R.E. Eckert, Jr. 1968(b). Germination of medusahead in response to osmotic stress. Weed Sci. 16:364-368.

APPENDIX

APPENDIX A

Plot Diagram



PLANT SPECIES BEING TESTED

1. California oatgrass *(Danthonia californica)*
2. Idaho fescue *(Festuca idahoensis)*
3. Junegrass *(Koeleria cristata)*
4. Tall wheatgrass *(Agropyron elongatum)*
5. Berber orchardgrass *(Dactylis glomerata)*
6. Paiute orchardgrass
7. Palestine orchardgrass
8. Perennial ryegrass *(Lolium perenne)*
9. Tall fescue *(Festuca arundinacea)*
10. Intermediate wheatgrass *(Agropyron intermedium)*
11. Rush wheatgrass *(Agropyron varnense)*
12. Non-use
13. Control, no vegetation
14. Control, resident annuals (no vispour)