INTERMOUNTAIN WEST NATIVE AND ADAPTED GRASS SPECIES AND THEIR MANAGEMENT FOR TURFGRASS APPLICATIONS

by

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TABLE OF CONTENTS

TABLE OF CONTENTS-CONTINUED

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES - CONTINUED

LIST OF FIGURES - CONTINUED

Figure | Page

ABSTRACT

This research addresses irrigation and water use of native and adapted grasses for turfgrass application. For this purpose, plots were established at the MSU Horticulture Research Farm, Bozeman, MT. The selected native and adapted grass species include 12 single species and 12 mixed species stands of ‘Cody’ buffalograss, ‘Foothills’ Canada bluegrass, ‘Bad River’ blue grama, sheep fescue, Sandberg bluegrass, muttongrass, and wheatgrasses ‘Sodar’ streambank, ‘Road Crest’ crested, ‘Rosana’ western, and ‘Critana’ thickspike with Kentucky bluegrass and tall fescue as introduced species. A line source irrigation system was installed to allow the plots to be evaluated at four irrigation levels. Experimental measurements on the plots included growth response as determined by clipping yield and quality ratings for color, texture, and density. Estimated timing and recommended minimum amount of water for irrigation for the grasses and mixtures for Bozeman, Montana, was determined from the data.

Single species and mixtures that had a good turf quality overall were sheep fescue, blue grama, buffalograss, and the mixture of buffalograss + sheep fescue. The single species and mixtures with adequate overall turfgrass were western wheatgrass and the mixtures of western wheatgrass + streambank wheatgrass, western wheatgrass + streambank wheatgrass + sheep fescue, blue grama + western wheatgrass, buffalograss + muttongrass, blue grama + muttongrass, and buffalograss + western wheatgrass. Canada bluegrass, crested wheatgrass, streambank wheatgrass, thickspike wheatgrass and the mixtures of Canada bluegrass + crested wheatgrass, and Canada bluegrass + western wheatgrass had poor overall turfgrass ratings and would not be recommended for turfgrass applications.

The results indicated that all the single species and mixtures required some irrigation for their optimum turfgrass quality. However, native and adapted grasses required less than or equal to the amount of supplemental irrigation needed by Kentucky bluegrass or tall fescue, and with many species and mixtures in the study, required a later recommended timing for irrigation.

LITERATURE REVIEW

Evolution and Benefits of Turfgrass

Turfgrass is defined as any grass that can be mowed, forming a dense ground cover (Christians, 2004). Turfgrass is used to prevent erosion, maintain visibility, reduce dust and glare, lower surface temperatures, add beauty, and provide a playable surface for athletics (Duble, 1996). Western civilization has domesticated wild grasses for these turfgrass characteristics dating back to the eighteenth century (Bormann, 1993).

Many of the species suited for turfgrass use evolved under grazing by herbivores. Having a meristematic region closer to ground level and an initiated defense mechanism for some grasses such as rhizomes, stolons, trichomes, siliceous dentations, alkaloids, phenolic compounds, and associations with endophytic fungi have all contributed to the co-evolution of grazing animals and grasses (Casler, 2003). It has also been shown that leaf growth rate and photosynthetic rate depends on periodic grazing in some perennial grasses (McNaughton, 1982). The evolution and physiology of certain perennial grasses lend themselves to selection for turfgrass purposes under mowing conditions. Out of more than 10,000 individual grass species throughout the world (Watson and Dallwitz, 1994), only a handful of those species are suited for turfgrass applications (Christians, 2004).

Turfgrass is a major component of managed landscapes throughout the United States, and is used for home lawns, subdivision common areas, commercial grounds, parks, cemeteries, athletic fields, golf courses, and highway rights-of-ways (Gould and Shaw, 1983). Turfgrass has many functional, recreational, commercial, and aesthetic benefits (Beard, 1994). Functional benefits include erosion control, dust prevention, solar heat dissipation, fire prevention, pollution entrapment, groundwater recharge, and environmental protection are examples of functional benefits of turfgrass. Recreational benefits include low-cost surfaces, safety and physical health, and appealing visual venues for spectators. Aesthetic benefits include community pride, improved quality of life, mental health, and complimenting trees and shrubs in the landscape.

Irrigation, Drought, and Water Conservation

Irrigation is the largest input required to maintain desired turfgrass quality and appearance throughout a growing season (Qian et al., 1999). The largest and most visible domestic use of water resources is the irrigation of a home lawn and landscape. A conventional turfgrass, such as Kentucky bluegrass, requires 1 to 1.5 inches of water per week during the growing season to retain its visual characteristics (Christians, 2004). The amount of water needed for a traditional turfgrass lawn to retain its visual quality is usually 2 to 3 times the amount of average annual precipitation in much of the Intermountain West. Current climatic changes and drought in the Intermountain West, combined with increased irrigation needs have created a net loss of water resources in reservoirs and aquifers.

A persistent drought has occurred in the Intermountain West because of years of below normal rainfall (www.NOAA.gov). The U.S. Drought Monitor through June of 2005 shows that most, if not all of the Intermountain West is abnormally to exceptionally dry (Figure 1.1).

This drought, coupled with the increasing demand for water resources caused by urban growth in the Intermountain West has led to water conservation efforts (Ervin and Koski, 1998). Conservation of water resources has far-reaching effects for farmers and ranchers who rely on irrigation to water, for industry, and for homeowners. Therefore, water conservation has become more socially accepted. Farmers and ranchers are now installing pivot lines, industry has been replacing old water consuming practices with water-wise practices, and homeowners are installing low-flow shower heads and low-gallon flushing toilets and teaching kids to turn off the water when brushing their teeth-all in an effort to reduce water consumption.

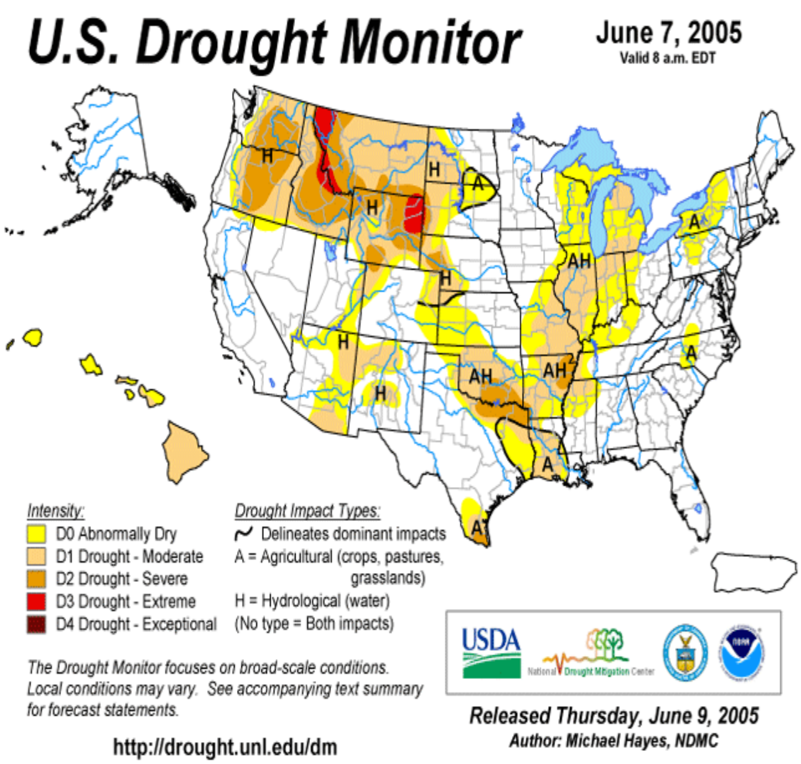

Figure 1.1 U.S Drought monitor, June 7, 2005. Showing much of the Intermountain West is experiencing a drought.

Home landscape irrigation accounts for more than one-half of the water used by an average household during the growing season. If culinary water is used, this will account for a decrease in the drinkable water supply and will increase expenditures for the water. Normal household water bills often double or even triple in summer months as compared to winter months (City of Bozeman, 2006). People in the Intermountain West are removing or reducing lawns in an effort to conserve water by decreasing their dependence on irrigation. In some instances, people are encouraged by water bill credits offered by municipalities to remove turfgrass (ASHS, 2005).

A study in Logan, Utah, revealed that most homeowners irrigated their lawns with little regard for the actual requirements of the grass (Aurasteh, 1984). The best way to conserve water is by using water more efficiently and minimizing the nonessential uses of that water is seen as a best strategy to conserve water (Bormann et al., 1993).   Bormann argues that "watering lawns that we have purposely designed to be thirsty is certainly a practice that needs to be re-evaluated." Understanding water requirements of differing grass species, not only will conserve water resources, but also is fundamental to plant health.

Increased pressure and interest in reducing irrigation have changed the market for landscape irrigation products. This trend in irrigation system technology has changed and is being developed to accommodate the need for water conservation. Technologies include smart systems, moisture sensors, interactive sensing, remote control, and pressure regulation (Vinchesi, 2002).   It is hoped that new technology in irrigation will reduce some of the dependency of water. However, technology has yet to produce an accepted drought-tolerant, sustainable turfgrass, especially one that can be sodded.

Traditional Introduced Turfgrass Species and Their Limitations

Traditional introduced species such as Kentucky bluegrass (*Poa pratensis*) and tall fescue (*Festuca arundinacea*) are used extensively throughout the Intermountain West for turfgrass applications. Kentucky bluegrass (KBG) is the most developed and propagated cool-season grass used in the turfgrass industry. KBG is held as a standard for comparison to all other cool-season turfgrasses because of its fine to medium texture, softness, high density, dark green color, and persistence. The manicured monolithic dark green appearance of traditional introduced turfgrass species is the social accepted norm. However, significant amounts of water and fertilizer are needed to keep these species lush and green (Bormann, 1993).

Managers in the turfgrass industry argue that KBG is the most drought-tolerant grass available (Bob Wagner, personal conversation). During times of drought, KBG and other traditional turf-type grasses enter dormancy, cease to grow, turn brown in color, and then recover when rainfall reoccurs. It is argued that there is nothing wrong with a tan lawn if someone chooses not to irrigate (Beard, 1994). This idea goes against many of the functional, recreational, and aesthetic benefits outlined by some of the same professionals who promote turfgrass. Dormant turfgrass does not have the benefit of solar heat dissipation, fire prevention, and aesthetic benefits such as beauty, mental health, social harmony, community pride, and increased property values. Furthermore, in areas with a high evaporation rate such as the Intermountain West, frequent drought conditions would cause traditional lawns to be soon replaced by local vegetation, including turfgrass weeds that are more adapted to the frequent drought conditions (Bormann, 1993).

Species Selection

Selection of drought-resistant grass varieties may be a way to save water (Bormann, 1993). Most low-maintenance turfgrass studies focus on traditional introduced species and cultivars for lower inputs such as nitrogen and water (Mintenko, 2002). Breeders have concentrated on genetic manipulation as well as cultivar selection of traditional introduced species for new low-maintenance releases. While selection of grass species for turfgrass is important, very few documented studies were conducted on native and adapted grasses for selection for turfgrass applications. No documented study has been performed on native and adapted grasses in the Intermountain West.

Introduced Grasses

Introduced grasses such as KBG and tall fescue are adapted to environmental temperature extremes, but need added inputs to flourish. Most traditional grasses are native to Europe and Asia and have been bred and selected for use in the United States. Turfgrasses that are dominated by introduced grasses are human modified ecosystems that routinely require chemical and physical inputs such as fertilizers, pesticides and irrigation, which account for negative environmental costs. These negative costs are pollution, contamination, and dewatering of aquifers, including streams, rivers, lakes and wetlands.

Kentucky Bluegrass

KBG is an introduced, highly rhizomatous medium-textured grass with a dark kelly green appearance when irrigated. Because it is heavily rhizomatous, KBG has a very high recuperative and reproductive capability, virtually “repairing itself” when damaged (Christians, 2004). For this reason, KBG is well adapted to areas such as home lawns, athletic fields, and parks and can be easily seeded or sodded. KBG has a shallow root system that demands more frequent and high amounts of water for its beneficial characteristics (Christians, 2004). It is highly drought tolerant because of its capability to remain dormant for several months, but requires on average, at least 28 inches of precipitation each growing season for an acceptable appearance (USDA, 2005). KBG is more cold tolerant than some of the other industry standards, such as tall fescue and perennial ryegrass (Christians, 2004,). KBG is tolerant to -33ºF (USDA, 2005), making it well-adapted to the Intermountain West temperature environment. KBG prefers fine- and medium-textured soils and does not flourish on coarse soils. The high fertility and water requirements for KBG make it a less desirable for a low-input sustainable turfgrass.

Tall Fescue

Tall fescue (*Festuca arundinacea*) is a coarse-textured grass that is weakly rhizomatous, but grows much more like a bunch grass. This introduced grass is cold tolerant to -38ºF and is considered drought tolerant, but most cultivars require a minimum of 24 to 30 inches of precipitation per year, even in an unmown situation (USDA, 2005). Tall fescue is considered a drought tolerant turfgrass because of its deep root system, although mowing height affects rooting depth (Christians, 2004). The lower tall fescue is mowed, the less root depth it will have making it arguably less drought tolerant. Tall fescue is adapted to fine- and medium-textured soils, and does not grow as well in coarse soils (USDA, 2005). It has a very rapid growth rate, thus requiring a medium fertility and irrigation level for acceptable appearance.

Native and Adapted Grasses

Grasses native to the Intermountain West have evolved to withstand extreme environmental conditions such as drought, low fertility, extreme seasonal temperatures, and grazing. Although most native grasses have not been evaluated for turfgrass purposes (Mintenko, 2002), native grasses of the Northern Great Plains may have the characteristics desired for a low-input sustainable turf (Holzworth, 1990). Selected native species have been evaluated in the Northern Great Plains Region (Mintenko, 2002) and in the Upper Midwest (Diesburg, 1997), but very little scientific research has been documented for the Intermountain West. Furthermore, there is very little documentation of grass mixtures used for low-input turfgrass situations.

Adapted grasses are non-native, but have many positive qualities, such as drought tolerance and winter hardiness, that enable them to survive in the Intermountain West climate. Unlike introduced turfgrasses, survival of adapted grasses is not dependent on amendments such as supplemental irrigation and additional fertilizer; therefore, they may be good candidates for turfgrass applications in the Intermountain West. Fertility and water requirements for most native and adapted grasses are known only for unmown conditions. Their naturally low water requirements make them excellent candidates for low input, but they are untested for turfgrass applications for the Intermountain West.

Canada Bluegrass, Sandberg Bluegrass, and Muttongrass

Native bluegrasses such as Canada bluegrass (*Poa compressa*), Sandberg bluegrass (*Poa secunda*), and Muttongrass (*Poa fendleriana*) are believed to have the physiological attributes desired for low-input, sustainable turf. Canada bluegrass is a fine-textured rhizomatous grass that is adapted to many soil textures, low fertility, and temperatures to -38ºF. Canada bluegrass has a medium drought tolerance with a minimum precipitation requirement of 20 inches under unmown conditions and has a green fine texture in mid-summer (USDA, 2005). Canada bluegrass has had intermediate success in the upper Midwest (Deisburg, 1997) and minimal success in the Northern Great Plains (Mintenko, 2002). Although Canada bluegrass showed promise as a low-input turfgrass, slow regrowth and loss of leaf material may distort the color of Canada bluegrass under low (under 3.5”) mowing conditions (Mintenko, 2002).

Sandberg bluegrass is a fine-textured green bunch grass native to North America. It is adapted to medium and coarse soils, has medium fertility requirements, and tolerates temperatures to -36ºF. It is very drought tolerant with a low moisture requirement of 8 to 16 inches per year under unmown conditions (USDA, 2005). Sandberg bluegrass has not been studied for turfgrass applications.

Muttongrass is a native fine-textured bluegrass that has a high drought tolerance requiring only 10 to 18 inches of annual precipitation to survive under unmown conditions. It is a fine textured green grass that tolerates coarse- and medium-textured soils and is winter hardy to -38ºF (USDA, 2005). Muttongrass has not been studied for turfgrass applications.

Streambank, Thickspike, Western Wheatgrass and Crested Wheatgrass

Wheatgrasses such as streambank wheatgrass (*Elymus lanceolatus*) and thickspike wheatgrass (*E. lanceolatus*), western wheatgrass (*Pascopyrum smithii*), and crested wheatgrass (*Agropyron cristatum*) have proven to be very drought and winter hardy. They create dense ground covers because of quick establishment (crested wheatgrass) and rhizomatous growth habit (streambank, thickspike, and western wheatgrass). In a study performed on native turfgrasses in a seven-state region throughout the upper Midwest, wheatgrasses performed better than other native species in the most western extent of the study (Mintenko, 2002). Wheatgrasses also have been observed by researchers in Kansas and Nebraska to perform well for low-maintenance turf (Diesburg, 1997).

Streambank and thickspike wheatgrass are ecologically distinct but are not taxonomically distinct because of “evolution from dry-site populations” (Lavin and Seibert, 2003). Streambank and thickspike wheatgrass are native rhizomatous grasses with a medium texture and variations of color from blue-green (streambank) to yellow-green (thickspike) and are able to establish a level surface suited for turfgrass application, including athletic fields (Holzworth, 1990). They are adapted to fine, medium, and coarse soils (USDA, 2005). However, streambank and thickspike wheatgrass prefer loam to coarse-textured soils with medium fertility when grown in an unmown situation (Holzworth, 1990). Streambank and thickspike wheatgrass are winter hardy; they survive temperatures to -38ºF, and are very drought tolerant, requiring less that 10 inches of precipitation per year in an unmown situation (USDA, 2005).

Western wheatgrass is another highly drought tolerant species that grows in 12-inch precipitation zones (Holzworth, 1990). It is adapted to fine- and medium-textured soils with a medium fertility requirement in an unmown situation. Western wheatgrass is medium- to coarse-textured blue-green grass that is cold-tolerant to -38ºF (USDA, 2005). Western wheatgrass grows readily along roadsides and is used extensively for erosion control (Lavin and Seibert, 2003).

Crested wheatgrass is an adapted, drought tolerant, bunch grass that only requires 5 inches of annual precipitation in an unmown situation and grows in almost any soil texture (Holzworth, 1990). It has medium-textured green foliage when irrigated and has a rapid growth rate. It is very cold-tolerant, withstanding temperatures to -43ºF.

Sheep Fescue

Found in many cool regions of the United States, including the Rocky Mountains, sheep fescue (*Festuca ovina*) is also broadly adapted to low-input sustainable turf in the upper Midwest (Diesburg, 1997). Sheep fescue is a non-native fine-textured bunch grass that needs very little inputs for a turfgrass situation. It is a common grass used in low-maintenance areas; however, only one variety, Quatro, is currently being marketed (Christians, 2004). This variety is drought tolerant, requiring less than 10 inches of precipitation per year. It grows well in medium- to coarse-textured soils, and can withstand temperatures to -43ºF (USDA, 2005), making it one of the most winter-hardy species in the Intermountain West. Fine fescue produces a higher quality turf in older stands as compared to KBG, and show greater tolerance to environmental stress than KBG and perennial ryegrass (Aronson, 1987). It is used extensively for unmown borders on golf courses and unmown hillsides (Christians, 2004). Sheep fescue's disadvantages include slow establishment and a bunch growth habit. Therefore, it is not recommended for athletic fields, but may be a worthy candidate for home lawns (Holzworth, 1990).

Buffalograss

Buffalograss (*Buchloe dactyloides*) is a native, warm-season, stoloniferous grass that has been investigated for turfgrass applications for nearly 20 years (Browning et al., 1994; Feldhake et al., 1984; McCarly and Colvin, 1992; Mintenko, 2002; National Turfgrass Evaluation Program, 1995; Qian et al., 1997). In fact, it is the only Intermountain West native grass used extensively in the United States for turfgrass applications (Casler and Duncan, 2003). Buffalograss is tolerant to extreme temperatures and prolonged drought, enabling it to survive extreme conditions within the environment. Buffalograss is a grey-green fine-textured grass and is recommended for low-maintenance and low-use turfgrass areas (Duble, 1996). It grows in fine- and medium-textured soils (USDA, 2005), rarely tolerating sandy soil (Duble, 1996). It is very drought tolerant, requiring a minimum of 7 inches of precipitation per year to survive, and is hardy to temperatures down to -28ºF (USDA, 2005). Buffalograss has performed well in the Turfgrass Transition Zone (Diesburg, 1997). In northern climates, winterkill may occur because mowing reduces root and crown reserves that are necessary to prevent winter damage (DiPaola and Beard, 1992). Late spring green-up and early fall dormancy have reflected low quality ratings for May and September in the Northern Great Plains region (Mintenko, 2002). Earlier establishment was very time consuming and expensive because buffalograss required plugging or sodding. However, buffalograss is gaining acceptance by turfgrass professionals because there are new cultivars that can be established by seed (Casler and Duncan, 2003; National Turfgrass Evaluation Program, 1995).

Blue Grama

Blue grama (*Bouteloua gracilis*) is a warm-season native bunch grass with fine-textured, grey-green foliage (Holzworth, 1990). Blue grama requires only 12 inches of precipitation per year to survive in an unmown situation and is cold hardy to -38ºF, making it both drought and cold tolerant. Blue grama grows in a wide range of soil textures and has a low fertility requirement (USDA, 2005). It has been used increasingly in golf course roughs in dry regions. Similar to buffalograss, it is adapted to both warm and cool arid climates (Christians, 2004). Blue grama has been rated high on turf quality in the Great Northern Plains, showing excellent drought tolerance, as well as good winter hardiness, color, texture, and adaptability to mowing stress (Mintenko, 2002). It is mainly planted on roadsides and other low-maintenance areas and has lost favor with turfgrass professionals as buffalograss has been improved (Christians, 2004)

Turfgrass Evaluation

The National Turfgrass Evaluation Program (NTEP) is the authority on turfgrass evaluation in North America, evaluating seventeen turfgrass species in as many as forty U.S. states and six provinces in Canada (NTEP, 2005). The evaluation includes both visual and functional qualities of turf. Visual qualities include density, texture, uniformity, color, growth habit, and smoothness. Functional qualities include rigidity, elasticity, resiliency, ball roll, yield, verdure, rooting, and recuperative capacity (Beard, 1994). Ratings are compared to traditional introduced grasses, such as cool-season

KBG and warm-season bermudagrass, because they set the standard for turfgrass quality. The National Turfgrass Evaluation Program rates grasses on a 1 to 9 score, with one being low quality and 9 being the utmost quality for turfgrass. For instance, turfgrass color would be rated as 1 = brown or yellow, 5 = light green, 7 = blue green, and 9 = dark green (Mintenko, 2002). Quality turfgrass ratings for native and adapted grasses are rarely evaluated in the NTEP program. Many native and adapted grasses may perform well as a turfgrass, but the color of these grasses may differ from that of conventional turfgrass species.

Study Goals and Objectives

The purpose of this experiment is to evaluate native and adapted grasses under mown conditions, and under line-source irrigation for yield, color, texture, and density. Timing and minimum amounts of irrigation to retain their optimum turfgrass qualities will be estimated for Bozeman, Montana.

Hypothesis 1: Native and adapted grasses will hold their desired turfgrass qualities under low water conditions.

Hypothesis 2: Mixtures of the adapted and native grasses will hold their desired turfgrass qualities under low water conditions.

Hypothesis 3: Native and adapted grasses and their mixtures will retain desirable turfgrass qualities while requiring less water than Kentucky bluegrass and tall fescue.

MATERIALS AND METHODS

Selection of Native and Adapted Grasses for Turfgrass Application

Ten native and adapted species and 12 native and adapted mixtures were selected for evaluation (Table 2.1). KBG and tall fescue were used as standard turfgrass. The study was conducted at the Montana State University Horticulture farm in Bozeman, Montana. Factors in the selection of turfgrass species included relevance to mean annual precipitation, plant winter hardiness, desired foliage texture and color, intended level of management, as well as soil texture, pH, and fertility (Holzworth, 1990). The native and adapted species in this study were chosen with these factors in mind, but were also chosen because of their drought tolerance, ability to adapt to the Intermountain West environment, natural landscape color, anecdotal turfgrass qualities, and commercial availability of seed. While many of the selected species have proven successful for forage and rangeland improvements in the Intermountain West, little is known about the impacts of drought stress and the optimum irrigation needed for native and adapted grass species in a turfgrass setting.

Mixture Selection

Species for the twelve mixtures were selected based on two criteria, photosynthesis mode (C3 vs. C4) and growth habit (rhizomatous, stoloniferous, and bunch). Cool season grasses (C3) and warm season grasses (C4) differ in their photosynthetic processes, thus making them more desirable for differing temperature regimes. Cool season grasses thrive in cooler temperatures (65°F to 75°F) and will grow rapidly in the spring and fall, while slowing their growth in mid-summer.

Table 2.1 Native, adapted, and introduced grass species selected for this study.

Single Species	Metabolism	Growth Habit	Relevance to Intermountain West	Source
'Cody' buffalograss	C4	Stoloniferous	Native	Granite Seed Co.
'Foothills' Canada bluegrass	C3	Rhizomatous	Native	BPMC
'Bad River' blue grama	C4	Bunch	Native	Circle S Seeds
'Road Crest' crested wheatgrass	C3	Bunch	Adapted	Granite Seed Co.
'Sodar' streambank wheatgrass	C3	Rhizomatous	Native	Circle S Seeds
'Rosana' western wheatgrass	C3	Rhizomatous	Native	Circle S Seeds
'Critana' thickspike wheatgrass	C3	Rhizomatous	Native	Circle S seeds
Sandberg bluegrass	C3	Bunch	Native	Circle S Seeds
Mutton grass	C3	Bunch	Native	Granite Seed Co.
'Covar' Sheep fescue	C3	Bunch	Adapted	BPMC
Tall fescue	C3	Bunch	Introduced	Granite Seed Co.
Kentucky bluegrass	C3	Rhizomatous	Introduced	Granite Seed Co.

Warm season grasses thrive in warmer temperatures (80°F to 95°F) and will grow rapidly in mid-summer and less in the spring and fall (Beard, 1973). Many of the mixtures selected contained both a warm- and a cool-season grass (Table 2.2). If there is minimal competition between the grasses, the turfgrass will retain its beneficial qualities throughout the entire growing season (Figure 2.1).

Table 2.2 Native and adapted grass species mixtures used in this study

Mixtures	**Contains both warm- and cool-season grasses**	**Contains rhizomatous or stoloniferous growth habits**
Buffalograss + Sandberg bluegrass		X
Buffalograss + Mutton grass	X	X
Buffalograss + sheep fescue	X	X
Buffalograss + blue grama + Sandberg bluegrass	X	X
Buffalograss + blue grama + Mutton grass	X	X
Buffalograss + western wheatgrass	X	X
Blue grama + Sandberg bluegrass	X	X
Blue grama + western wheatgrass	X	X
Western wheatgrass + streambank wheatgrass + sheep fescue		X
Western wheatgrass + streambank wheatgrass		X
Canada bluegrass + western wheatgrass		X
Canada bluegrass + crested wheatgrass		X

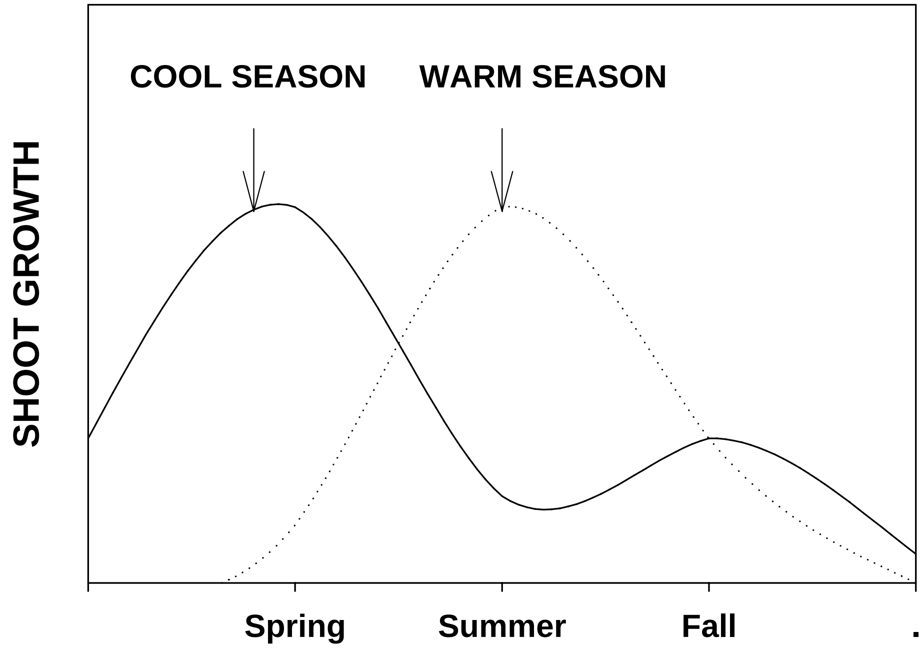

Figure 2.1 The seasons effect on shoot growth pattern of cool-season and warm-season grasses. Figure adopted from Fundamentals of Turfgrass (Christians, 2004)

Pairing a sod-forming rhizomatous or stoloniferous species with that of a bunch type species was another factor in mixture selection. Many of the chosen bunchgrasses have the desired turfgrass qualities, but because of their growth habit, may not be suited for the sod producing industry. Because the turfgrass industry uses both seeding and sodding techniques for establishment, mixtures were chosen to accommodate both (Table 2.2).

Experimental Design and Procedures

Ninety-six test plots were established in a split-plot design in a 70 by 264 feet field orientated east-west to lessen the effect of the prevailing winds from the west (Figure 2.2).

70'

35'

Sandberg bluegrass	'Sodar' Streambank wheatgrass
Tall fescue	Sheep fescue
Buffalograss + Muttongrass	Canada bluegrass + Crested wheatgrass
'Bad River' Blue grama	Buffalograss + Western wheatgrass
Sheep fescue	Buffalograss + Sheep fescue
'Foothills' Canada bluegrass	'Roadcrest' Crested wheatgrass
Muttongrass	Kentucky bluegrass
Western wheatgrass + Streambank wheatgrass	'Critana' Thickspike wheatgrass
'Rosana' Western wheatgrass	Buffalograss + Blue grama + Muttongrass
'Sodar' Streambank wheatgrass	Blue grama + Sandberg Bluegrass
'Cody' Buffalograss	Tall fescue
Buffalograss + Sandberg Bluegrass	Sandberg bluegrass
Buffalograss + Blue grama + Sandberg Bluegrass	Buffalograss + Muttongrass
'Roadcrest' Crested wheatgrass	'Rosana' Western wheatgrass
Kentucky bluegrass	Buffalograss + Blue grama + Sandberg Bluegrass
Buffalograss + Blue grama + Muttongrass	Canada bluegrass + Western wheatgrass
Buffalograss + Western wheatgrass	Blue grama + Western wheatgrass
Blue grama + Sandberg Bluegrass	'Foothills' Canada bluegrass
Western wheatgrass + Streambank wheatgrass + Sheep fescue	Western wheatgrass + Streambank wheatgrass
Blue grama + Western wheatgrass	Muttongrass
Buffalograss + Sheep fescue	Buffalograss + Sandberg Bluegrass
'Critana' Thickspike wheatgrass	'Bad River' Blue grama
Canada bluegrass + Crested wheatgrass	'Cody' Buffalograss
Canada bluegrass + Western wheatgrass	Western wheatgrass + Streambank wheatgrass + Sheep fescue
Blue grama + Sandberg Bluegrass	Buffalograss + Sandberg Bluegrass
'Foothills' Canada bluegrass	Kentucky bluegrass
Buffalograss + Sheep fescue	'Roadcrest' Crested wheatgrass
Canada bluegrass + Western wheatgrass	'Rosana' Western wheatgrass
'Rosana' Western wheatgrass	Western wheatgrass + Streambank wheatgrass
Buffalograss + Blue grama + Muttongrass	Western wheatgrass + Streambank wheatgrass + Sheep fescue
Tall fescue	Canada bluegrass + Crested wheatgrass
Kentucky bluegrass	Buffalograss + Blue grama + Sandberg Bluegrass
Buffalograss + Western wheatgrass	Buffalograss + Blue grama + Muttongrass
Buffalograss + Muttongrass	'Sodar' Streambank wheatgrass
Buffalograss + Blue grama + Sandberg Bluegrass	'Cody' Buffalograss
Muttongrass	'Foothills' Canada bluegrass
Sandberg bluegrass	Sheep fescue
Buffalograss + Sandberg Bluegrass	Tall fescue
'Roadcrest' Crested wheatgrass	'Critana' Thickspike wheatgrass
'Cody' Buffalograss	Sandberg bluegrass
Canada bluegrass + Crested wheatgrass	Muttongrass
'Critana' Thickspike wheatgrass	Buffalograss + Sheep fescue
Western wheatgrass + Streambank wheatgrass + Sheep fescue	Blue grama + Western wheatgrass
Western wheatgrass + Streambank wheatgrass	Blue grama + Sandberg Bluegrass
Sheep fescue	Canada bluegrass + Western wheatgrass
Blue grama + Western wheatgrass	'Bad River' Blue grama
'Bad River' Blue grama	Buffalograss + Muttongrass
'Sodar' Streambank wheatgrass	Buffalograss + Western wheatgrass

5.5'

264'

← North

Line-source irrigation

Figure 2.2 The experimental design of the native, adapted, and introduced grass monostands and mixture plots at the MSU Horticulture Farm. Dark Lines deliniate replicate blocks

The plots containing the individual grasses and mixtures measured 5.5 by 35 feet and were placed perpendicular to a line-source irrigation system that ran lengthwise through the center of the field. The plots were replicated four times. Each of the main plots were then divided into four equal sub-plots measuring 5.5 by 8.75 feet. Moisture level were labeled L1, L2, L3, and L4, with L1 being closest to the line-source. Each sub-plot represented an amount of water applied; with the amount of water decreasing the further the subplot was from the line-source irrigation.

The subplots closest to the line-source (L1) received an average of 1.00 inches per week of moisture by precipitation and supplemental irrigation. The second subplot form the line-source irrigation (L2) received an average of 0.75 inches of precipitation and supplemental irrigation per week. The third subplot from the line-source irrigation (L3) received 0.33 inches of moisture, and the last subplot (L4) only received 0.10 inches on average per week (Figure 2.3).

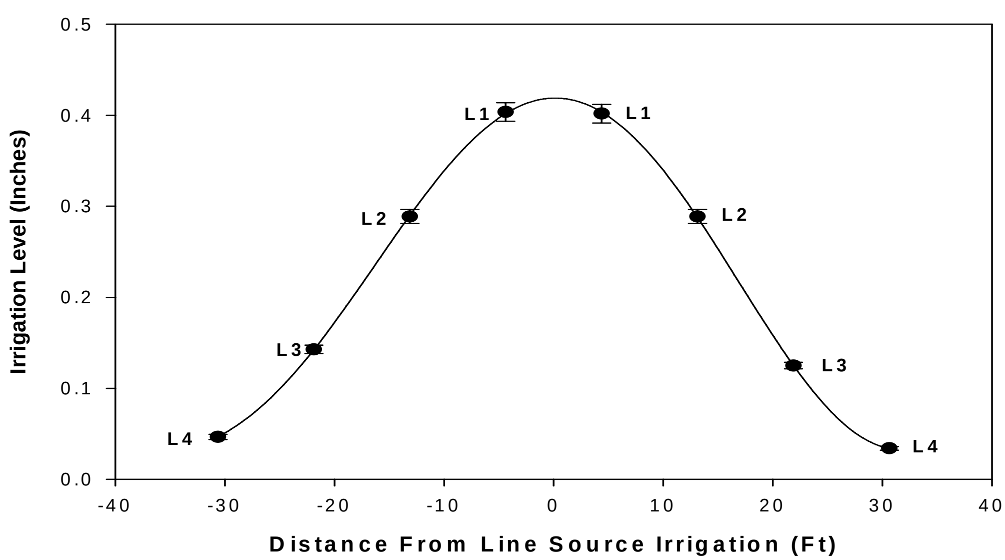

Figure 2.3 Average twice weekly supplemental irrigation as related to the distance from the sprinkler line source for native and adapted turfgrass study at Bozeman, Montana 2005

Field Establishment

Preparation of the plots consisted of working the field with a harrow and hand-raking the field to create an even planting area. The seed was measured for each sub-plot at a rate of 500 pure live seed (PLS) per square foot. For mixtures, the rates were divided evenly among species. The seed was then evenly broadcast on each sub-plot. The seed was then raked into the seed bed with a common garden rake. To eliminate air pockets and to enhance seed-soil contact, the plots were rolled over using a garden roller.

Irrigation

The irrigation was a two-part system, one for establishment, the other for the line source irrigation. Both irrigation systems consisted of pop-up adjustable impact sprinkler heads with 2.6-gallon-per-minute nozzles (MAXIPAW™, Rainbird Corporation, Glendora, California). The water pressure at the main line was 65 pounds per square inch . This gave the sprinkler heads a throw of 35 feet. For establishment irrigation, the system was trenched lengthwise on both edges of the field prior to planting and heads were spaced every 33 feet for head-to-head irrigation (Figure 2.4).

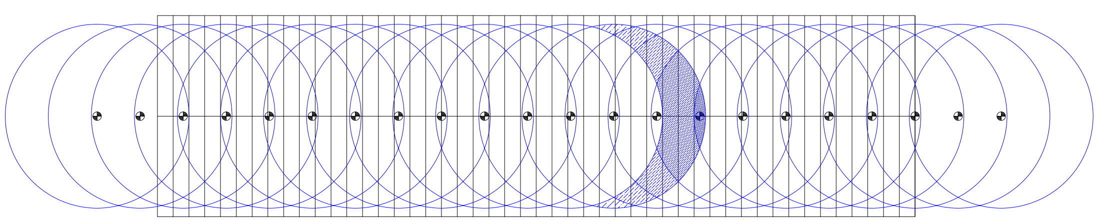

Figure 2.4 Head placement and coverage of irrigation system for Native and Adapted Grass Species for Turfgrass Evaluation study at Bozeman, Montana, 2005.

Another line was trenched lengthwise through the center of the plots and heads were spaced every 30 feet. In the second season the center line was used as part of the line source irrigation. During the establishment period, plots were irrigated at an average rate of three-quarters of an inch per week throughout the growing season, depending on the prevailing temperature and precipitation conditions.

The line-source configuration allowed for the irrigation system to be uniform along the length of the plot, but uniformly variable across the plot (Hanks, 1976). For line-source irrigation, a second distribution pipe was placed in the center trench of the field prior to planting. The heads of this pipe were spaced every 30 feet and were offset from the first center line such that the heads were spaced every 15 feet. Head spacing was less than 25 percent of the wetted diameter of the plots. The overlapping radii of the heads achieved the line-source effect, thus the plots nearest the line-source received the most irrigation. The remaining subplots received uniformly less irrigation the farther they were located from the line-source (Figure 2.5).

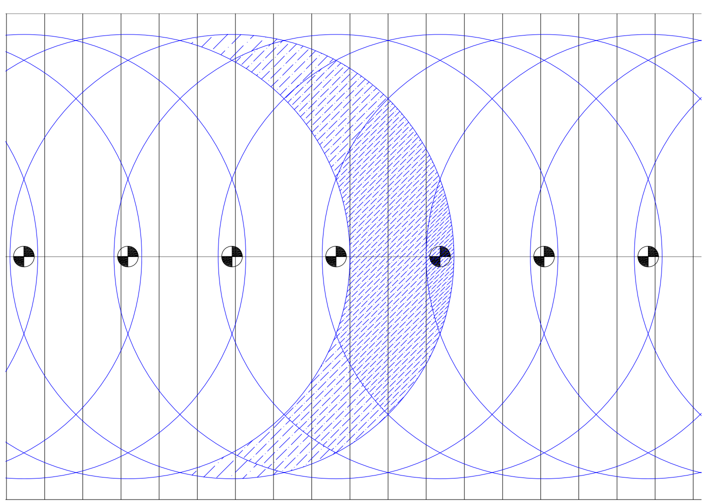

Figure 2.5 Line-source irrigation water coverage. Irrigation amounts decreases the farther the plot is from the irrigation system, creating a gradient of moisture.

To test precipitation and distribution, catch cups were placed randomly throughout the study plots. Plots were irrigated and the system was monitored such that subplots closest to the line-source received one inch of water per week. The irrigation supplemented natural precipitation (Figure 2.6).

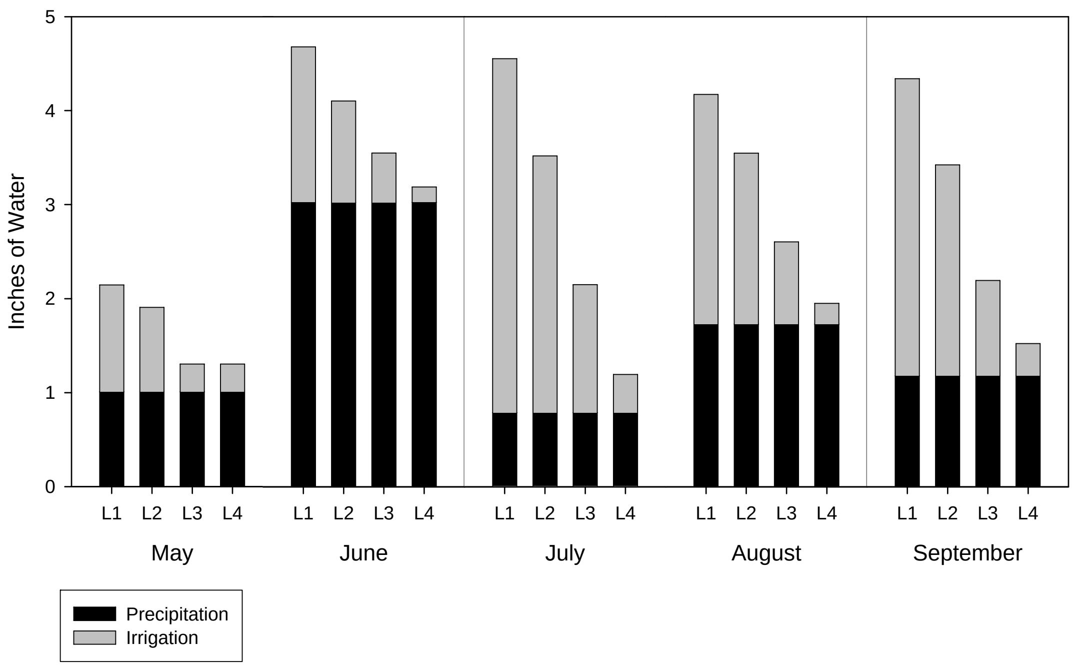

Figure 2.6 Monthly precipitation and irrigation averages for the Bozeman, MT study. L1=High moisture subplots, L2=Medium moisture subplots, L3= Low moisture subplots, L4=Very low moisture subplots

Plot Maintenance

Once established, the plots were mowed weekly to a height of 3 inches. The plots were fertilized with 1lb per 1000 square feet with ammonium nitrate (34-0-0) in the fall of 2004 and again in the spring of 2005. Two applications of Confront™ herbicide, with active ingredients of 33.0% triclopyr and 12.1% clopyrid, were applied to control the annual and perennial broadleaf weed population. The first application was applied in the fall of 2004 at a rate of 1 pint per acre. The second application was applied in the late spring of 2005 at a rate of 2 pints per acre.

Data Collection and Statistical Analysis

Hypothesis 1: Native and adapted grasses will hold their desired turfgrass qualities under low water conditions.

Monthly measurements were performed to find dry weight, and to rate the color, texture, and density of the single species and mixtures. Once a month, immediately prior to the weekly mowing, a randomly selected 25 square centimeter section of each subplot was harvested above 3 inches. The clipped material was dried in a drying oven at 70ºC for 48 hours and weighed to find the dry weight.

Following the clipping collection, and prior to the weekly mowing, the entire plots were evaluated for color, texture, and density using NTEP guidelines (NTEP) Color was rated on a 1 to 9 scale with one equaling straw brown and nine equaling dark green. Texture was measured on a 1 to 9 scale with one equaling coarse texture and nine equaling fine texture. Density was measured using a 1 to 9 scale with one equaling bare ground and nine equaling maximum density. The data for single species was analyzed within species using the SAS mixed model. (SAS Institute, Cary, NC).

Hypothesis 2: Mixtures of the adapted and native grasses will hold their desired turfgrass qualities under low water conditions.

Plots containing mixtures were evaluated monthly using the same steps outlined above. The data was analyzed as to whether the mixtures held their turfgrass quality consistently throughout the season.

Hypothesis 3: Native and adapted grasses and their mixtures will retain desirable turfgrass qualities while requiring less water than Kentucky bluegrass and tall fescue.

The data was analyzed and general characteristics of the plots' overall turfgrass color, texture, and density were considered. A generalization was then made about whether each monostand or mixture had overall turfgrass qualities and was labeled a good, fair, or poor turfgrass.

The recommended minimum moisture and timing of irrigation needed for optimum turfgrass quality of the single species and mixtures was found by plotting the one-hundred-year-weekly average precipitation for Bozeman, Montana, against the minimum moisture needed each month for each grass or mixture to retain its optimum turfgrass quality. Minimum water requirements for optimum turfgrass quality were determined by selecting the subplot with the least amount of irrigation which retained statistically the highest ratings for color, texture, and density. The timing for irrigation was determined when the precipitation no longer sustained optimum turfgrass quality. The point at which the two plots intersected was the estimated time in which irrigation should begin. The recommended minimum weekly irrigation required was calculated by subtracting the highest minimum moisture amount of the season from the average weekly precipitation.

Bozeman, Montana is situated in the Rocky Mountains and has a comparable environment and climate to much of the Intermountain west. The recommended timing and level of irrigation was based on the average precipitation for Bozeman. The data from Bozeman, Montana study can be applied to anywhere in the Intermountain west by substituting their average weekly precipitation of other areas and evaluating the data.

RESULTS

Results for Turfgrass Quality

Kentucky Bluegrass

There was a significant month by subplot interaction for KBG when evaluating color (Figure 3.1a). May and June color ratings were similar for all subplots. In July there was a significant decrease in color ratings and a divergence of L1 and L2 subplots from L3 and L4 subplots. From July to September the color ratings of L1 and L2 subplots were significantly higher than the L3 and L4 subplots. Both L3 and L4 subplots regained some color in September, but were still significantly less than the L1 and L2 subplots.

The texture rating for KBG had a significant month by subplot interaction (Figure 3.1b). Texture ratings for all plots increased significantly from May to June, but then decreased significantly from June to July. There was a divergence in August, where the L1 and L2 subplots had statistically higher texture ratings than the L3 and L4 subplots. All subplots remained unchanged from August. The density ratings of KBG followed the same pattern as the texture ratings, but the L3 and L4 subplots densities were a bit higher in August and September (Figure 3.1c).

Dry weight showed significant differences caused by month main effects (Figure 3.1d). Only May, August, and September had significantly lower weights than June and July. There was a significant increase to a peak weight in June.

Kentucky Bluegrass

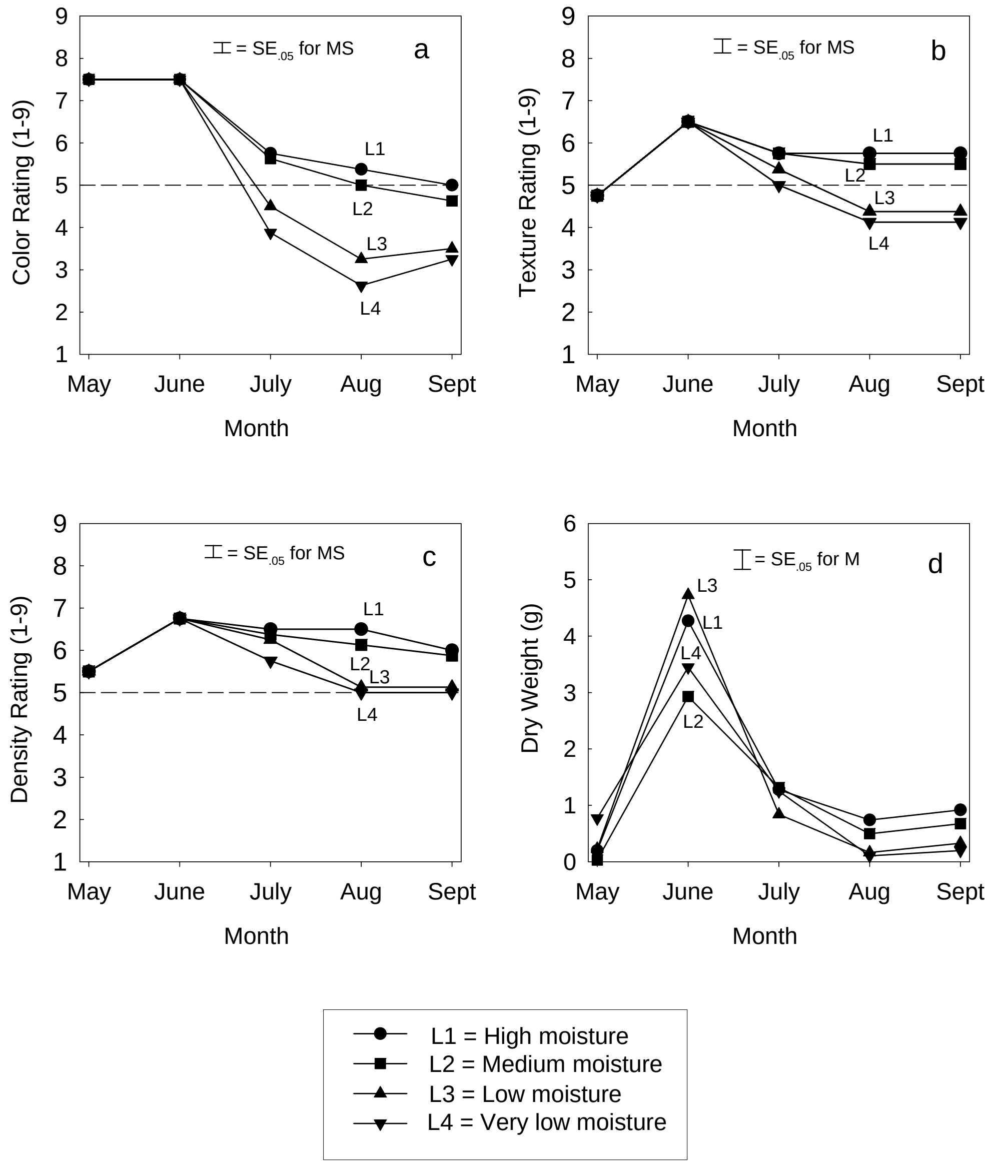

Figure 3.1 Effect of month and moisture level on (a) color (b) texture, (c) density, and (d) dry weight of Kentucky bluegrass. Color was rated on a 1 to 9 scale with 1 being straw brown and 9 being dark green. Turfgrass texture was rated on a 1 to 9 scale with 1 equaling coarse and 9 equaling fine. Density was rated on a 1 to 9 scale with 1 being bare ground and 9 equaling maximum density.

Each point represents a mean of four replicates. Error bars indicate difference of least square means standard error ($p<0.05$) for the M=month main effect, S=subplot main effect, or MS=month x subplot interaction.

Tall Fescue

The color rating for tall fescue had a significant month by subplot interaction (Figure 3.2a). All subplots were similar in May and June. From June to September, the color ratings decreased significantly. There was a divergence in subplot ratings starting in July. By August and into September, the L1 and L2 subplots were significantly greener than the L3 and L4 subplots. The L3 and L4 subplots increased from August to September, while the L1 and L2 subplots continued to decrease.

A month by subplot interaction occurred in both texture and density ratings. For texture ratings, measurements varied within 0.5 units, making statistically significant differences visually indiscernible (Figure 3.2b). Density, on the other hand, had a significant 3 unit variation. Within subplots, densities were similar in May and June, with subplots significantly denser in June than in May. From June to September, there was a divergence among the subplots in which the L1 and L2 subplots remained significantly denser than the L3 and L4 subplots. The L1 and L2 densities remained above the acceptable level of 5, while the L3 and L4 subplots were below (Figure 3.2c).

Dry weight significant differences were cause by both month and subplot main effects (Figure 3.2d). The dry weight of the L3 subplot was statistically lower than only the L1 and L4 subplots.

Canada Bluegrass

The color rating for Canada bluegrass had month and subplot main effects (Figure 3.3a). The color rating decreased significantly from May to July. From July to August, the ratings leveled off at ratings between 3 and 4, and slightly increased from August to September. The color ratings for the L1 subplot were significantly higher

Tall Fescue

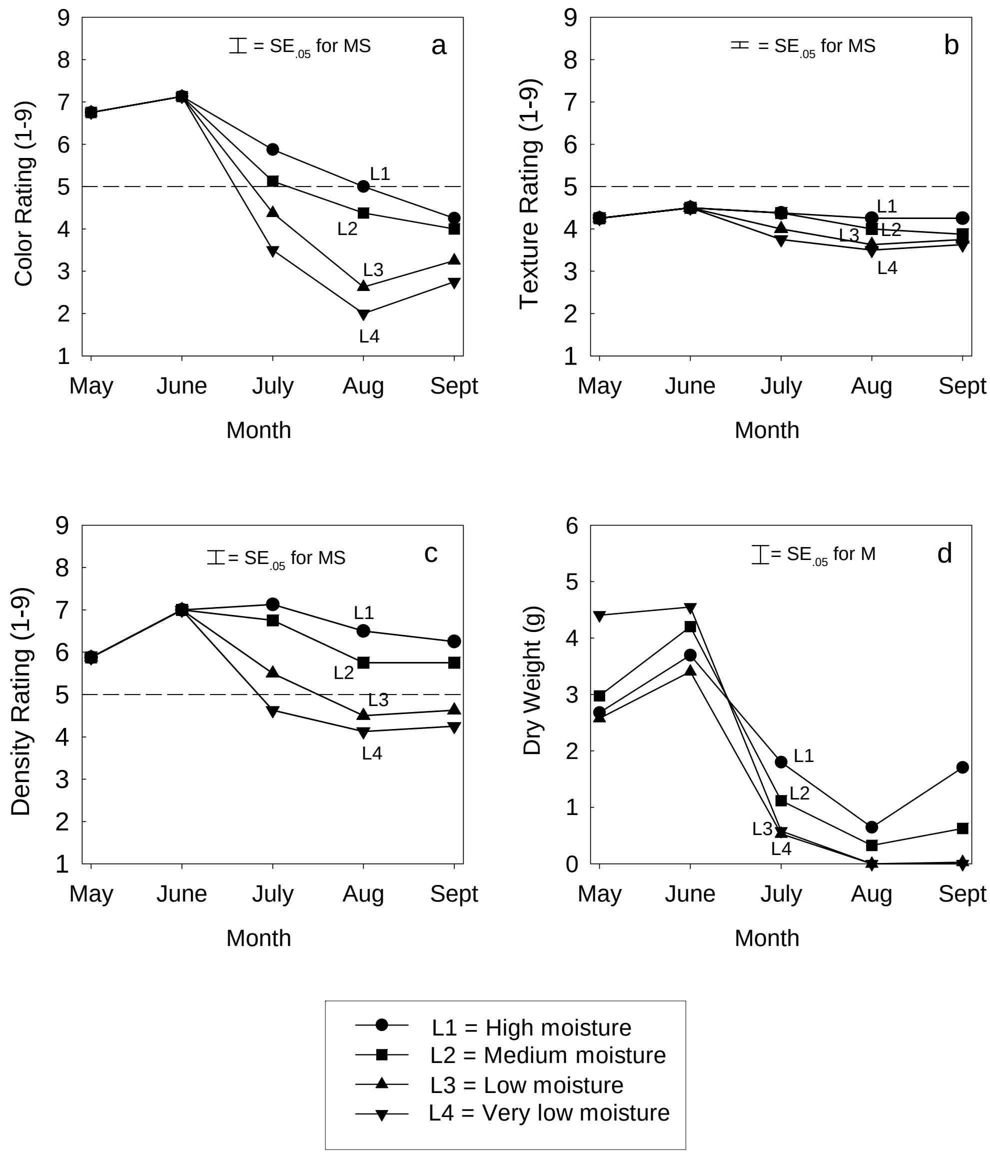

Figure 3.2 Effect of month and moisture level on (a) color (b) texture, (c) density, and (d) dry weight of Tall fescue. Color was rated on a 1 to 9 scale with 1 being straw brown and 9 being dark green. Turfgrass texture was rated on a 1 to 9 scale with 1 equaling coarse and 9 equaling fine. Density was rated on a 1 to 9 scale with 1 being bare ground and 9 equaling maximum density.

Each point represents a mean of four replicates. Error bars indicate difference of least square means standard error ($p<0.05$) for the M=month main effect, S=subplot main effect, or MS=month x subplot interaction.

Canada Bluegrass

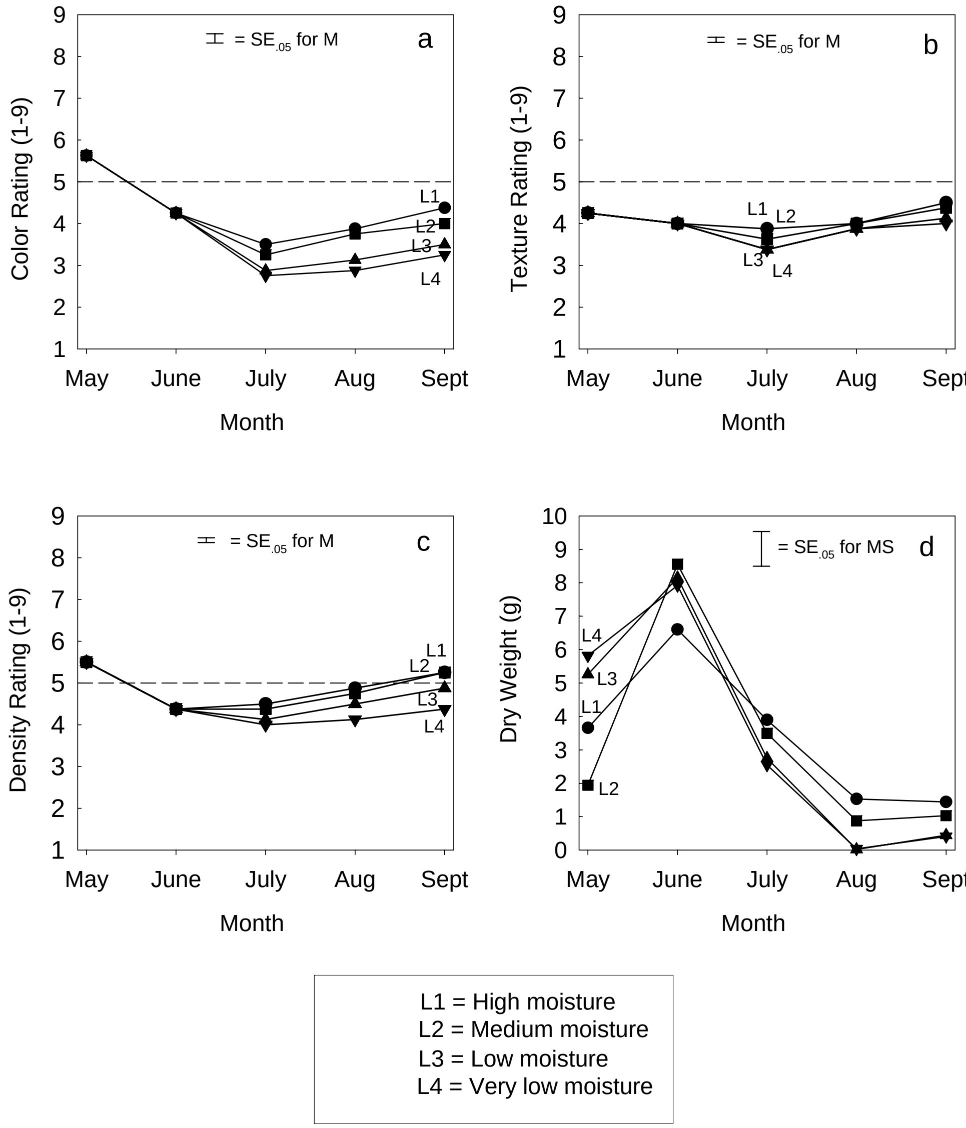

Figure 3.3 Effect of month and moisture level on (a) color (b) texture, (c) density, and (d) dry weight of Canada bluegrass. Color was rated on a 1 to 9 scale with 1 being straw brown and 9 being dark green. Turfgrass texture was rated on a 1 to 9 scale with 1 equaling coarse and 9 equaling fine. Density was rated on a 1 to 9 scale with 1 being bare ground and 9 equaling maximum density.

Each point represents a mean of four replicates. Error bars indicate difference of least square means standard error (p<0.05) for the M=month main effect, S=subplot main effect, or MS=month x subplot interaction.

than the color ratings for theL3 and L4 subplots. The color rating of the L2 subplot was statistically higher than the L4 subplot.

The texture rating for Canada bluegrass had a month main effect (Figure 3.3b). In May the texture ratings averaged just over 4. The ratings lowered slightly in July and rebounded through August and September. Texture ratings fluctuated at most one point on a scale of 1-9, a difference the human eye would barely discern.

Density ratings had month and subplot main effects (Figure 3.3c). Density decreased from May to June, then increased from July to September. Density of L1 and L2 subplots was significantly higher than L3 and L4 subplots.

Dry weight in Canada bluegrass had a significant month by subplot interaction (Figure 3.3d). Because of the rain episodes in May, dry weights during the month were high, with the L3 and L4 subplots yielding the statistically highest weight. From May to June the dry weights of the subplots statistically increased, but all subplot dry weights in June were not significantly different. Dry weights statistically decreased from June to August. Dry weights for August and September were not significantly different from one another, but were significantly lower than the previous months.

Crested Wheatgrass

Color ratings for crested wheatgrass had both month and subplot main effects (Figure 3.4a). Color ratings significantly decreased from May with a rating of 4, to July where ratings were between 2.6 and 3.6. From July to September, color ratings remained consistent, with ratings from 2.5 to 4.1. Subplot main effects were that the color ratings for L1 and L2 subplots were significantly higher than the L3 and L4 subplots.

Crested Wheatgrass

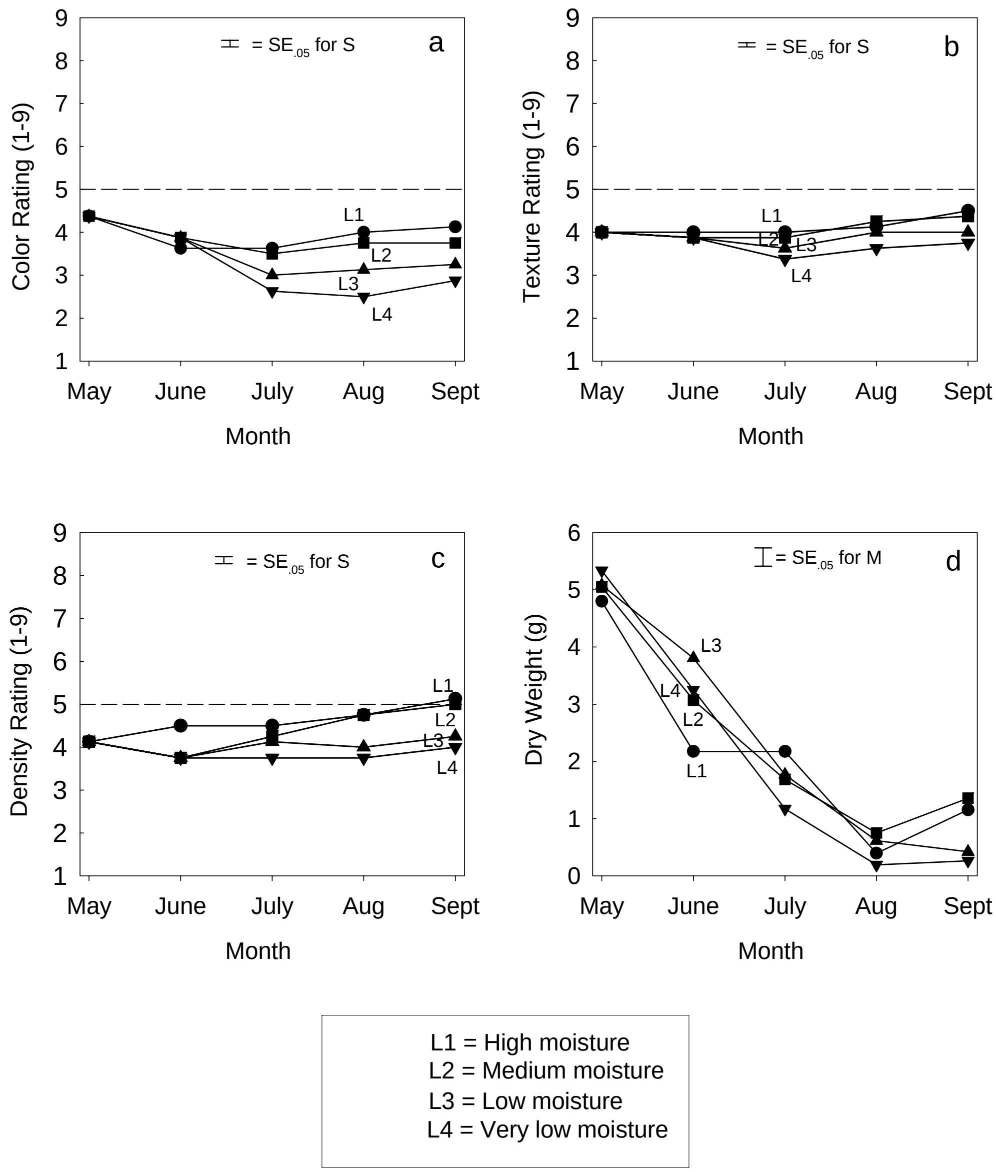

Figure 3.4 Effect of month and moisture level on (a) color (b) texture, (c) density, and (d) dry weight of crested wheatgrass. Color was rated on a 1 to 9 scale with 1 being straw brown and 9 being dark green. Turfgrass texture was rated on a 1 to 9 scale with 1 equaling coarse and 9 equaling fine. Density was rated on a 1 to 9 scale with 1 being bare ground and 9 equaling maximum density.

Each point represents a mean of four replicates. Error bars indicate difference of least square means standard error ($p<0.05$) for the M=month main effect, S=subplot main effect, or MS=month x subplot interaction.

Texture and density ratings had month and subplot main effects; although ratings increased slightly during the summer, the changes were not visually significant (Figure3.4b,c).

Significant differences among dry weights for crested wheatgrass were caused by month main effects (Figure 3.4d). Plant weights were highest in May, with both parameters significantly decreasing from May until August. Plant weight decreased the most from May to June, and slowly decreased from June to August.

Muttongrass

Muttongrass was not evaluated due to its low vigor and a lack of competition with weeds. Although muttongrass grows well in the greenhouse under manipulated controls, in the field it was poor to establish and was out-competed by annual and perennial broadleaf and grass weeds. This created a situation in which it was impossible to collect data.

Sandberg Bluegrass

Sandberg bluegrass was not evaluated because of less than pure seed stock, in which a range type tall fescue in the mixture overtook the plots making evaluations impossible. The canopy of the plots was dominated by tall fescue and other weeds, thus out-competing Sandberg bluegrass.

Sheep Fescue

There was a significant month by subplot interaction in the rating of color for sheep fescue (Figure 3.5a). Color ratings in May and June were 6.1 and 6.2

Sheep Fescue

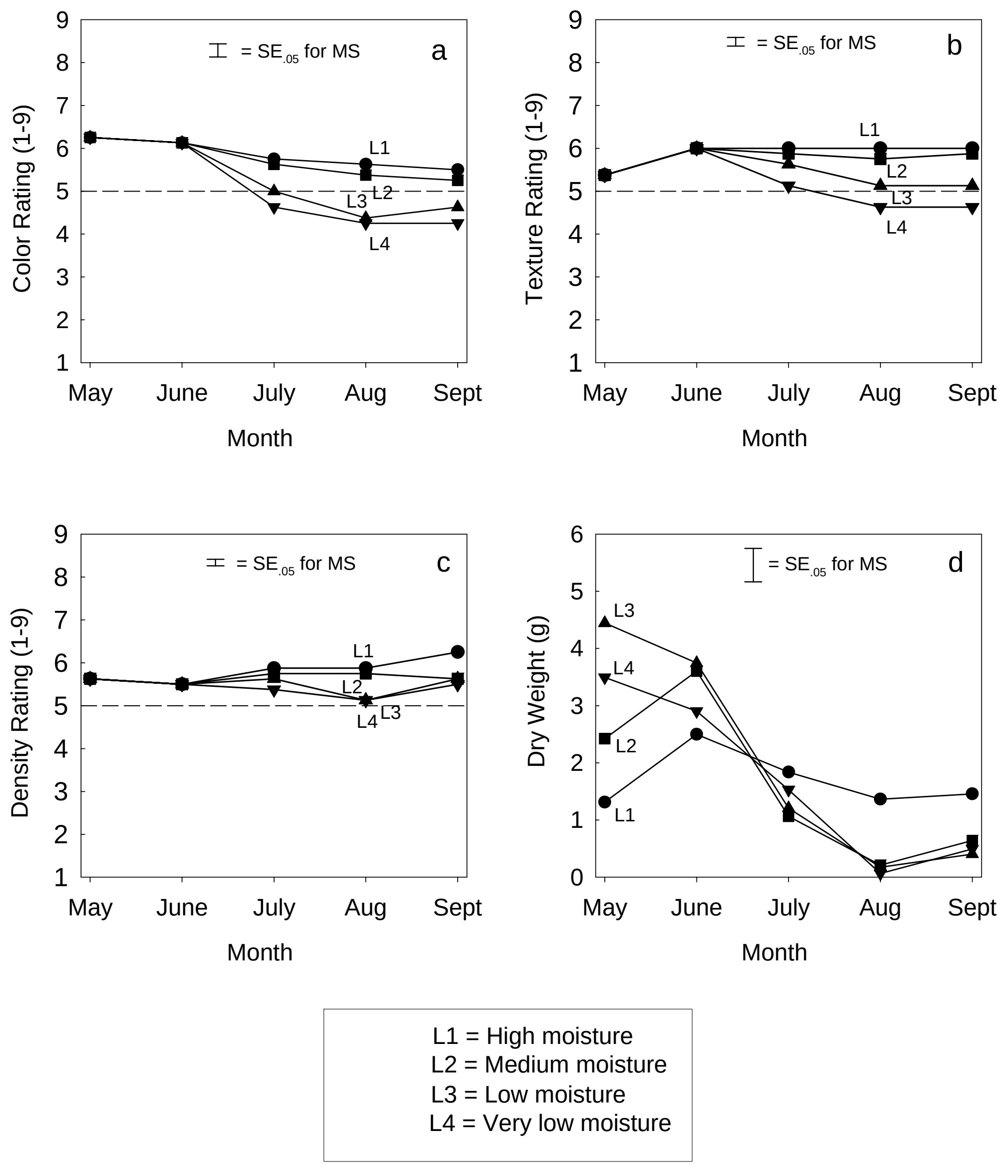

Figure 3.5 Effect of month and moisture level on (a) color (b) texture, (c) density, and (d) dry weight of sheep fescue. Color was rated on a 1 to 9 scale with 1 being straw brown and 9 being dark green. Turfgrass texture was rated on a 1 to 9 scale with 1 equaling coarse and 9 equaling fine. Density was rated on a 1 to 9 scale with 1 being bare ground and 9 equaling maximum density.

Each point represents a mean of four replicates. Error bars indicate difference of least square means standard error ($p<0.05$) for the M=month main effect, S=subplot main effect, or MS=month x subplot interaction.

respectively. In July, there was divergence in which the L1 and L2 subplots color ratings were significantly higher than the L3 and L4 subplots. By August, the L1 and L2 subplots color remained above the accepted rating of 5, and was significantly higher than the L3 and L4 subplots.

Texture and density had significant month by subplot interactions, although differences were within one unit, a range narrowly discernable by the human eye. Texture ratings remained high with only the L4 subplot falling below the accepted level, and significantly lower than rest of the subplots (Figure 3.5b). Density rating differences likely would not be dicernable and were above the accepted rating of 5 (Figure 3.5c).

Dry weight for sheep fescue had a significant month by subplot interaction (Figure 3.5d). Weights did not follow convention in the first month; the weights for L1 and L2 subplots were significantly lower than the L3 and L4 subplots. Weights for L3 and L4 subplots had a significant drop throughout the summer, while the L1 subplot remained consistent throughout the summer. The L2 subplot had significantly higher weights in June rather than in May.

Streambank Wheatgrass

Differences in color ratings for streambank wheatgrass were caused by both a month and a subplot main effect (Figure 3.6a). The color for streambank wheatgrass was highest in May. The color ratings fell significantly from May to July. The color rating remained low for the remainder of the season with only a slight increase from August to September. The L1 and L2 subplots overall were significantly higher than the L3 and L4 subplots.

Streambank Wheatgrass

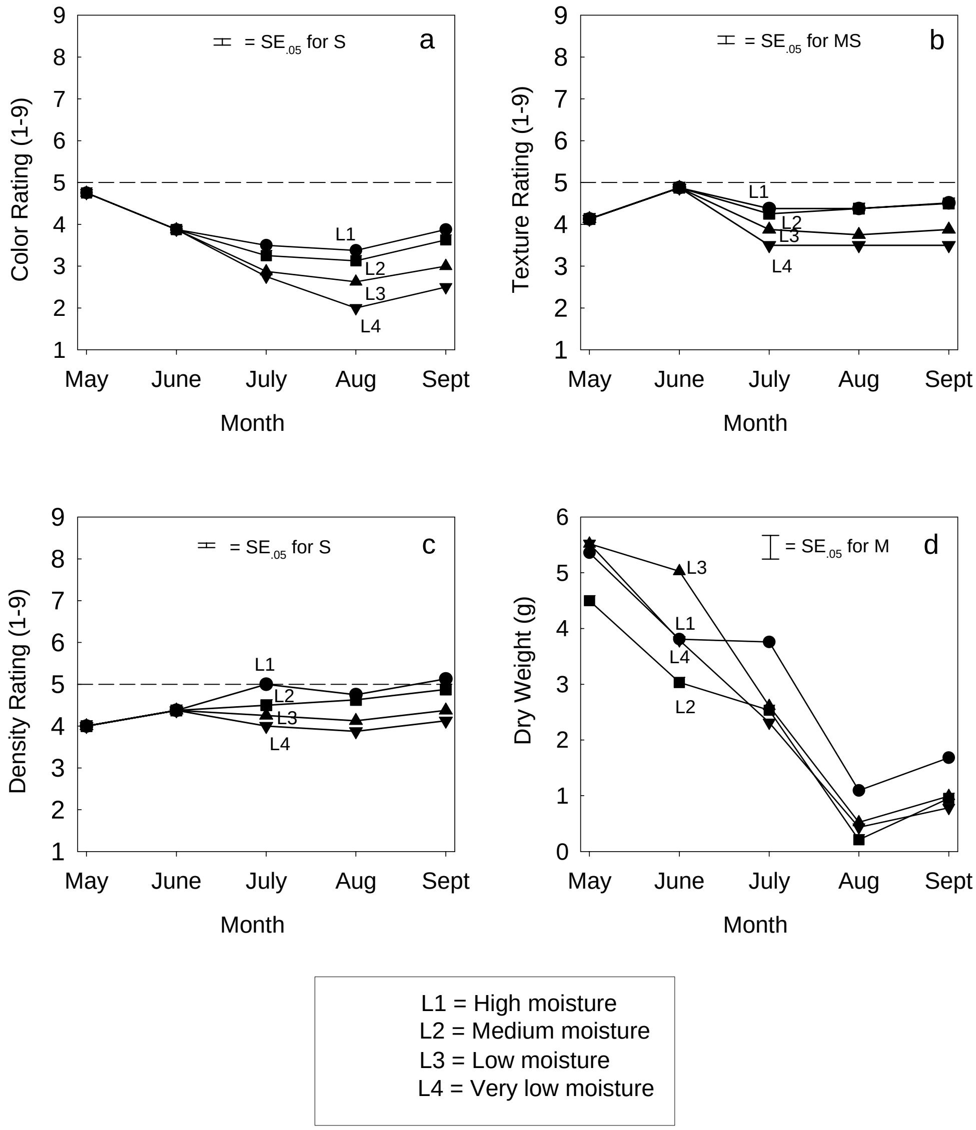

Figure 3.6 Effect of month and moisture level on (a) color (b) texture, (c) density, and (d) dry weight of streambank wheatgrass. Color was rated on a 1 to 9 scale with 1 being straw brown and 9 being dark green. Turfgrass texture was rated on a 1 to 9 scale with 1 equaling coarse and 9 equaling fine. Density was rated on a 1 to 9 scale with 1 being bare ground and 9 equaling maximum density.
Each point represents a mean of four replicates. Error bars indicate difference of least square means standard error ($p<0.05$) for the M=month main effect, S=subplot main effect, or MS=month x subplot interaction.

Differences in texture ratings for streambank wheatgrass were caused by a significant month by subplot interaction, although the change was within one unit (Figure 3.6b). The texture of the grass was below the acceptable level, except in June, where all subplots were near the acceptable level of 5. Significant differences in density were caused by both a month and subplot main effects (Figure 3.6c). Densities increased significantly from May to June and leveled off for the remainder of the year, although like texture, the change was within one unit.

Month main effects caused the significant differences in dry weight in streambank wheatgrass (Figure 3.6d). Plant weights and water content were highest in May. Plant weights significantly decreased from May to August. Plant water content dropped significantly from May to July, and significantly dropped again from July to September.

Thickspike Wheatgrass

Month and subplot main effects were significant for color, texture, and density for thickspike wheatgrass (Figure 3.7a,b,c). The highest color rating was in May. In June, August and September, color ratings were similar. July had the lowest color rating. Color ratings decreased with decreasing moisture levels. A small but significant texture increase occurred in July over all other months. Although there was a subplot main effect, the textural differences among subplots was within one unit. The subplots density increased significantly from May to September. Similar to texture, density differences among subplots were within one unit.

Thickspike Wheatgrass

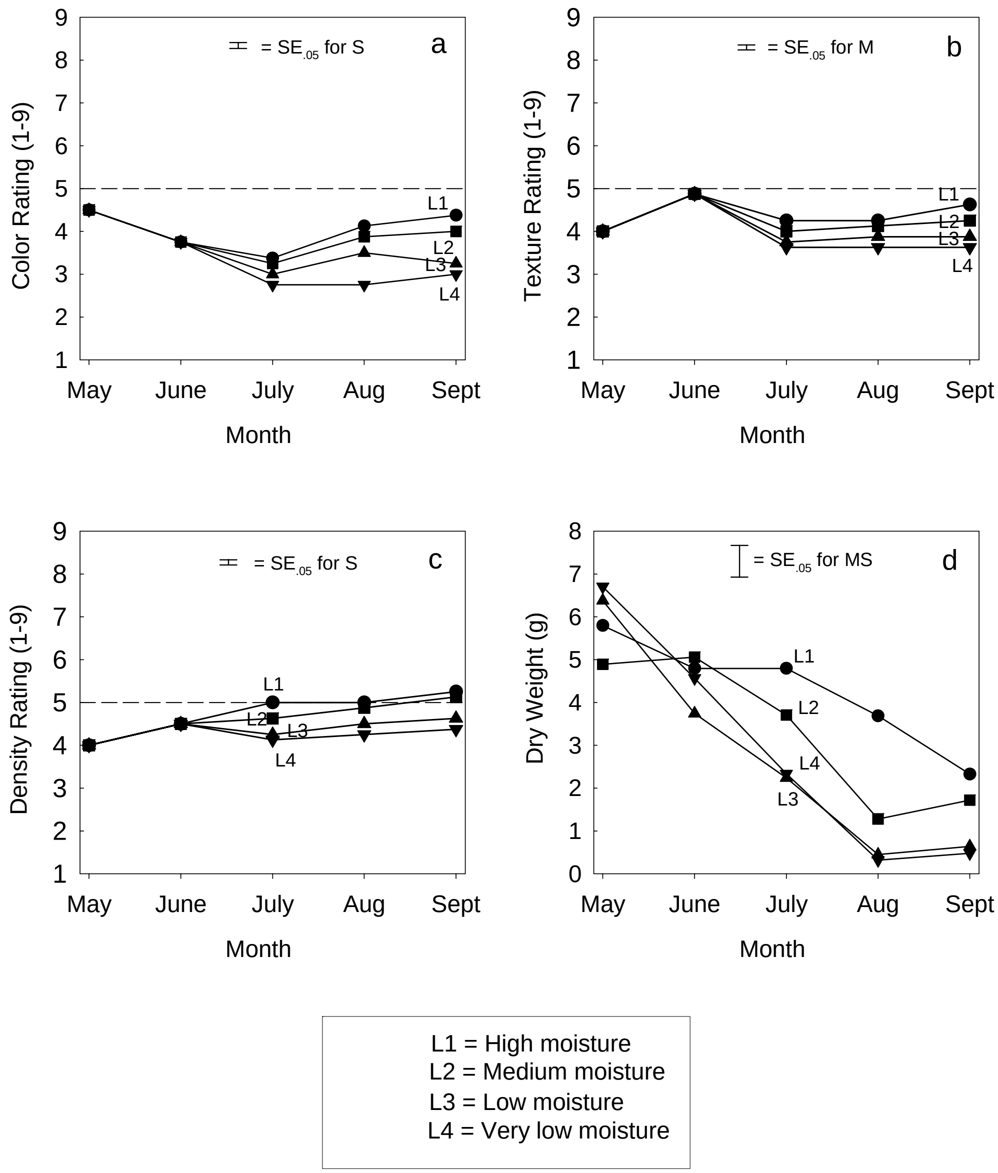

Figure 3.7 Effect of month and moisture level on (a) color (b) texture, (c) density, and (d) dry weight of thickspike wheatgrass. Color was rated on a 1 to 9 scale with 1 being straw brown and 9 being dark green. Turfgrass texture was rated on a 1 to 9 scale with 1 equaling coarse and 9 equaling fine. Density was rated on a 1 to 9 scale with 1 being bare ground and 9 equaling maximum density.

Each point represents a mean of four replicates. Error bars indicate difference of least square means standard error ($p<0.05$) for the M=month main effect, S=subplot main effect, or MS=month x subplot interaction.

There was a significant month by subplot interaction for and dry weight of thickspike wheatgrass (Figure 3.7d). In May, the L4 subplot produced the significantly highest dry weight. In June the subplot plant weights converged. Plant weights dropped significantly from June to September. The L2, L3, and L4 subplots dropped weight significantly faster than the L1 subplot. The L1 subplot decreased in weight less drastically, but eventually had low weights in September, similar to the other subplots.

Western Wheatgrass

Color rating significant differences were caused by month and subplot main effects (Figure 3.8a). The color rating remained fairly level throughout the season, although July, August and September were statistically less than May and June. Color ratings of L1 and L2 subplots were significantly higher than the L3 and L4 subplots.

Texture ratings had a month by subplot interaction (Figure 3.8b). The texture of western wheatgrass was highest in June, with a divergence of the L1 and L2 subplots from the L3 and L4 subplots by September. However, the differences between subplots were within 0.5 units. Density ratings were caused by month and subplot main effects (Figure 3.8c). Density ratings increased statistically in the later part of the season, but again would have been hard to observe because the increases were also within one unit.

The significant differences in dry weight of western wheatgrass were caused by month main effects (Figure 3.8d). Dry weights were significantly higher from May to June, but decreased significantly from June to August.

Western Wheatgrass

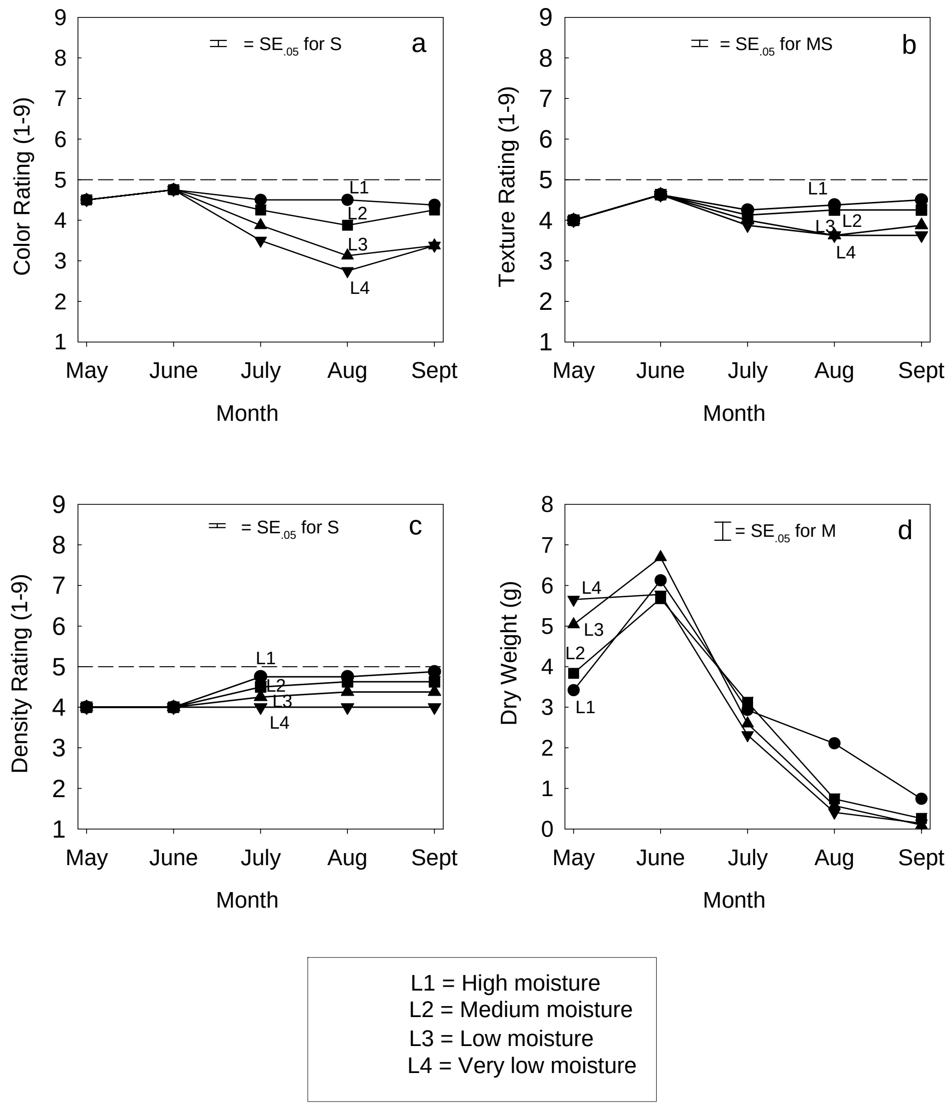

Figure 3.8 Effect of month and moisture level on (a) color (b) texture, (c) density, and (d) dry weight of western wheatgrass. Color was rated on a 1 to 9 scale with 1 being straw brown and 9 being dark green. Turfgrass texture was rated on a 1 to 9 scale with 1 equaling coarse and 9 equaling fine. Density was rated on a 1 to 9 scale with 1 being bare ground and 9 equaling maximum density.

Each point represents a mean of four replicates. Error bars indicate difference of least square means standard error ($p<0.05$) for the M=month main effect, S=subplot main effect, or MS=month x subplot interaction.

Blue Grama

The color rating for blue grama had a significant month by subplot interaction (Figure 3.9a). All subplot color ratings significantly increased from May to June, but slowly and significantly decreased from June to September. However, subplot color ratings diverged in July when the L1 subplot was significantly higher than the L4 subplot. This divergence continued into August, when L1 and L2 levels remained near the accepted level of 5 and significantly differed from that of L3 and L4 subplots, which dropped off quickly to a rating near 3. The color ratings for all subplots decreased dramatically in September, when all subplots were statistically the same, all with ratings under 2.

Texture rating for blue grama showed only a month main effect. All months were statistically different from one another except July from August (Figure 3.9b). Like the color ratings, texture ratings peaked in June, with a rating just below 7, and slowly decreased the remainder of the summer to a rating average of around 4.5.

The month main effect for density was significant, with July to August statistically denser than May, June, and September (Figure 3.9c). Subplot main effects were evident. The densities of subplots L1 and L2 were significantly higher than the subplots L3 and L4.

The significant differences in dry weight of blue grama were caused by month main effects (Figure 3.9d). May and September had no measured dry weight, as the grass was dormant during those months. Plant weights were highest in June, significantly decreased from June throughout the summer.

Blue Grama

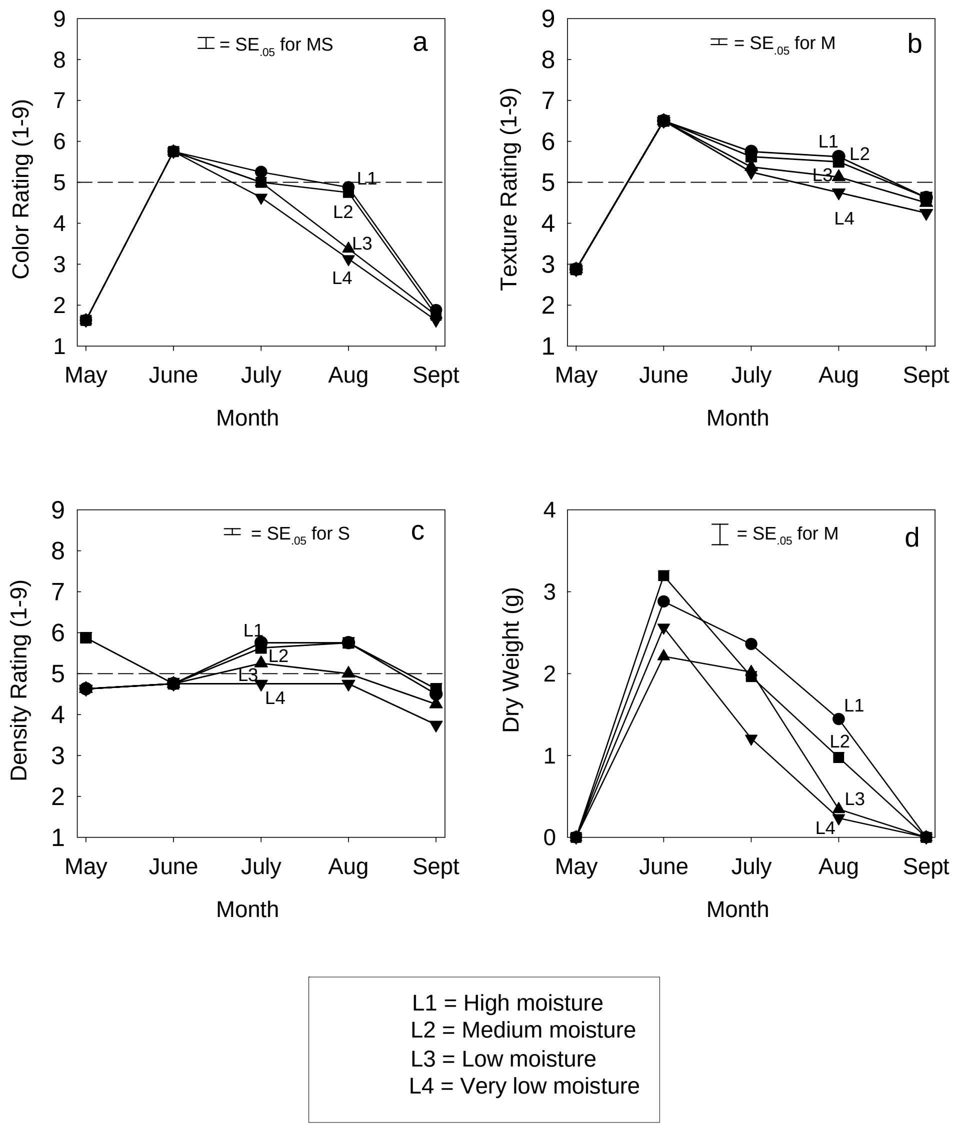

Figure 3.9 Effect of month and moisture level on (a) color (b) texture, (c) density, and (d) dry weight of blue grama. Color was rated on a 1 to 9 scale with 1 being straw brown and 9 being dark green. Turfgrass texture was rated on a 1 to 9 scale with 1 equaling coarse and 9 equaling fine. Density was rated on a 1 to 9 scale with 1 being bare ground and 9 equaling maximum density.

Each point represents a mean of four replicates. Error bars indicate difference of least square means standard error ($p<0.05$) for the M=month main effect, S=subplot main effect, or MS=month x subplot interaction.

Buffalograss

The color rating for buffalograss had a month main effect in which all months were significantly different from one another except May from September (Figure 3.10a). Color ratings showed a statistical increase from May to June, but decreased the following months.

The texture of buffalograss showed both a month and subplot main effect (Figure 3.10b). The month main effect showed that texture was significantly highest in July and August. Like the color ratings, texture ratings increased from May to June and decreased from June to September. Texture subplot main effect showed that subplots L1 and L2 were significantly higher than subplot L4.

There was a month by subplot interaction for density of buffalograss (Figure 3.10c). The density of buffalograss increased significantly from May until July. In the month of July there was a divergence in which the subplots L1 and L2 were significantly denser than the subplots L3 and L4. In August, the densities of the subplots were statistically similar to those in July. The L4 subplot density decreased such that it was statistically less that the density of subplot L3. In September, as buffalograss went into dormancy, the density ratings of all the subplots were near 2.

There was a significant month by subplot interaction for buffalograss in dry weight (Figure 3.10d). No clippings were taken May and September because the grass was dormant and not growing. In June, dry weight of the L3 subplot was significantly higher compared to the other subplots. In July, dry weights increased for all subplots except the L4 subplot, which saw a slight decrease. The weight of the L2 subplot increased the most, with a dry weight that was significantly higher than the L1

Buffalograss

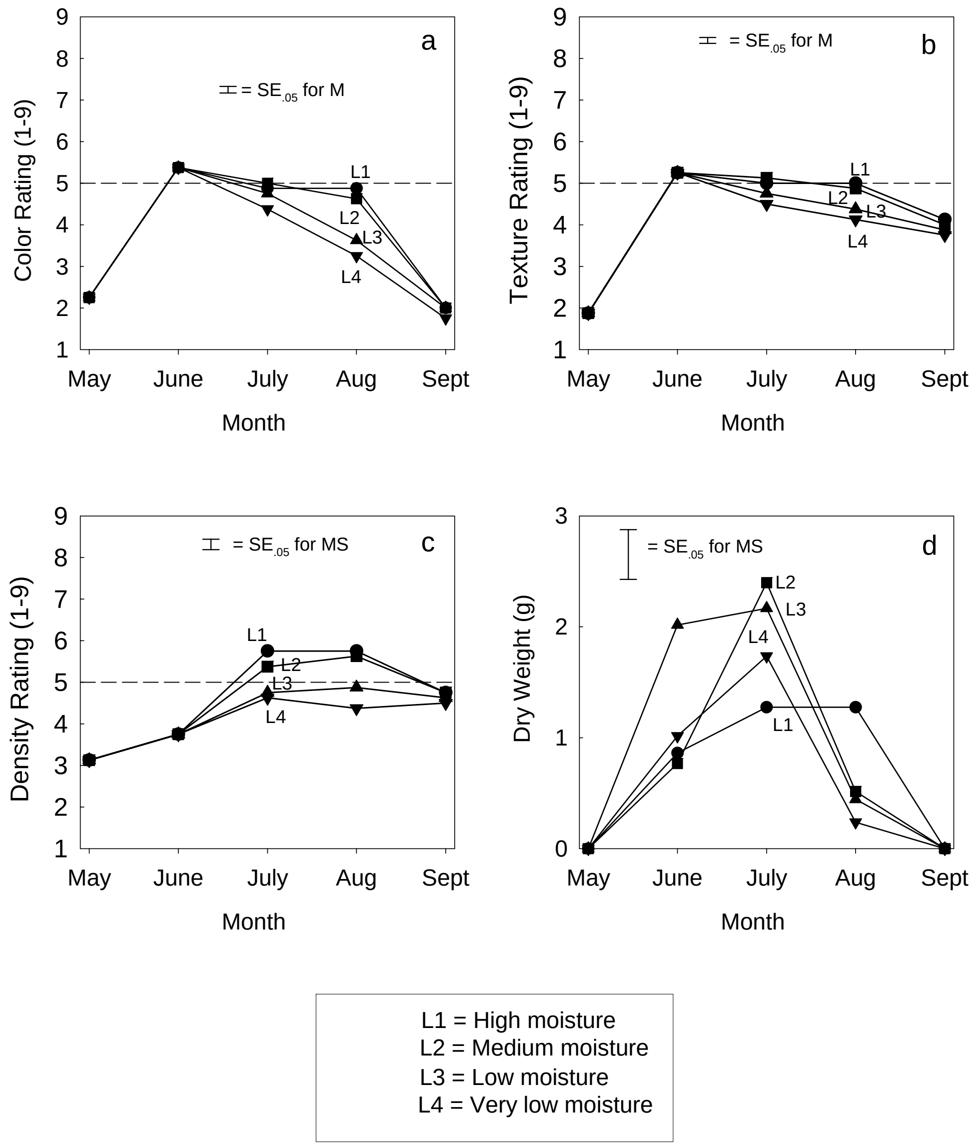

Figure 3.10 Effect of month and moisture level on (a) color (b) texture, (c) density, and (d) dry weight of buffalograss. Color was rated on a 1 to 9 scale with 1 being straw brown and 9 being dark green. Turfgrass texture was rated on a 1 to 9 scale with 1 equaling coarse and 9 equaling fine. Density was rated on a 1 to 9 scale with 1 being bare ground and 9 equaling maximum density.

Each point represents a mean of four replicates. Error bars indicate difference of least square means standard error ($p<0.05$) for the M=month main effect, S=subplot main effect, or MS=month x subplot interaction.

subplot but statistically similar to the remaining plots. The month of August saw a sharp decrease in dry weights of the L2, L3, and L4 subplots, but the L1 subplot remained nearly the same weight. The L1 subplot was significantly higher than the L4 subplot, but was significantly similar to the L2 and L3 subplots. The L2, L3, and L4 subplots were statistically similar in the month of August.

Canada Bluegrass + Crested Wheatgrass

The color rating of the mixture of Canada bluegrass + crested wheatgrass mixture had month and subplot main effects (Figure 3.11a). Color ratings decreased significantly from May to July, leveled off in August, and then increased significantly in September. The L1 and L2 subplots had significantly higher color ratings than the L3 and L4 subplots.

Texture and density of the mixture had significant differences caused by month main effects (Figure 3.11b,c). From May to July, ratings for texture and density significantly decreased, but then increased significantly from July to September.

Significant differences in dry weight for the Canada bluegrass + crested wheatgrass mixture were caused by month main effects (Figure 3.11d). There was a significant decrease in dry weights from June to August.

Canada Bluegrass + Western Wheatgrass

The color ratings for the mixture of Canada bluegrass + western wheatgrass had month and subplot main effects (Figure 3.12a). Color ratings remained similar in May and June but decreased significantly from June to July. The color ratings were similar from July to September. The L1 and L2 subplots were significantly higher than the L3 and L4 subplots.

Canada Bluegrass + Crested Wheatgrass

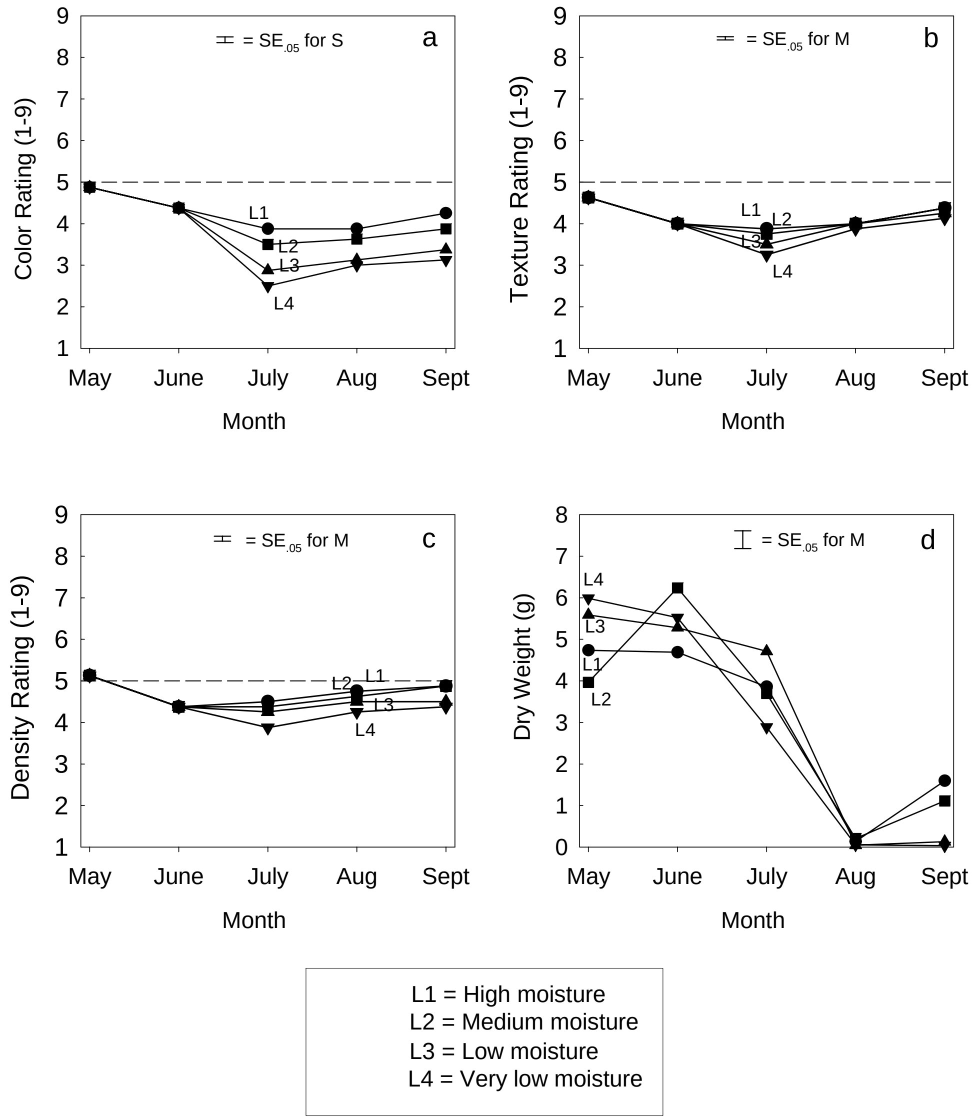

Figure 3.11 Effect of month and moisture level on (a) color (b) texture, (c) density, and (d) dry weight of Canada blugrass + crested wheatgrass. Color was rated on a 1 to 9 scale with 1 being straw brown and 9 being dark green. Turfgrass texture was rated on a 1 to 9 scale with 1equaling coarse and 9 equaling fine. Density was rated on a 1 to 9 scale with 1 being bare ground and 9 equaling maximum density.

Each point represents a mean of four replicates. Error bars indicate difference of least square means standard error ($p<0.05$) for the M=month main effect, S=subplot main effect, or MS=month x subplot interaction.

Canada Bluegrass + Western Wheatgrass

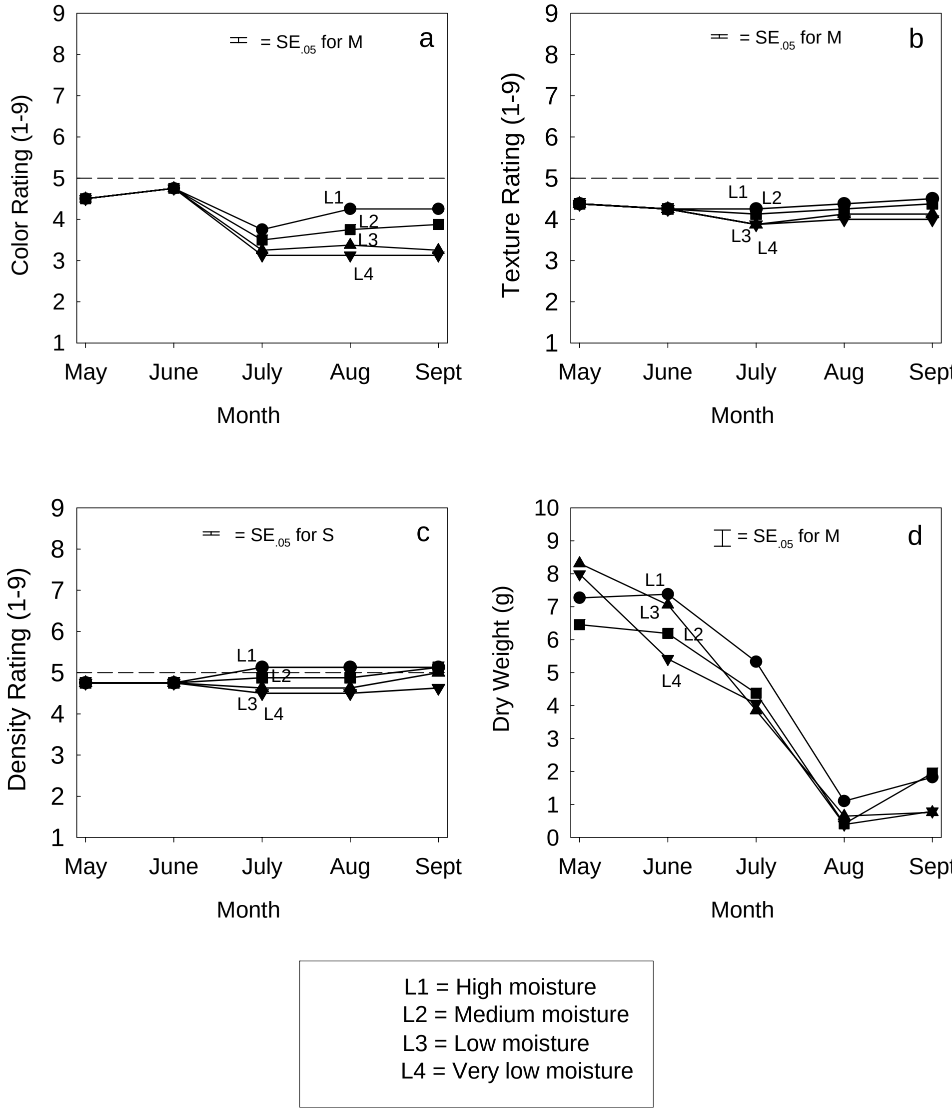

Figure 3.12 Effect of month and moisture level on (a) color (b) texture, (c) density, and (d) dry weight of Canada bluegrass + western wheatgrass. Color was rated on a 1 to 9 scale with 1 being straw brown and 9 being dark green. Turfgrass texture was rated on a 1 to 9 scale with 1equaling coarse and 9 equaling fine. Density was rated on a 1 to 9 scale with 1 being bare ground and 9 equaling maximum density.

Each point represents a mean of four replicates. Error bars indicate difference of least square means standard error ($p<0.05$) for the M=month main effect, S=subplot main effect, or MS=month x subplot interaction.

Texture ratings had month and subplot main effects, while density ratings of the mixture only had a subplot main effect (Figure 3.12b,c). Although there were main effects in both cases, the differences were within one rating unit.

Dry weight had significant differences caused by month main effects (Figure 3.12d). The dry weights for this mixture were highest in May and significantly decreased in every month except September.

Western Wheatgrass + Streambank Wheatgrass

There was a significant month by subplot interaction for the color ratings of the western wheatgrass + streambank wheatgrass mixture (Figure 3.13a). Subplot color ratings decreased significantly from May to June. In July a divergence occurred in which the L3 and L4 subplot had statistically lower ratings than the L1 and L2 subplots. This divergence remained through September.

Differences in textures were caused by a month by subplot interaction (Figure 3.13b). Textures increased significantly in June but decreased significantly in July. There was a divergence of the subplots in July. The L3 and L4 subplots were significantly less than the L1 subplot. By September, the L3 and L4 subplots were significantly lower than the L1 and L2 subplots.

Density differences were caused by a significant month by subplot interaction (Figure 3.13c). Densities among the subplots remained similar from May to June. There was a significant increase of the L1 and L2 subplots from June to September. In September, the L1 and L2 subplots were significantly higher than the L3 and L4 subplots.

Dry weight had a significant month by subplot interaction (Figure 3.13d). In May, the L3 and L4 subplots were significantly higher than the L2 subplot. The L2

Western Wheatgrass + Streambank Wheatgrass

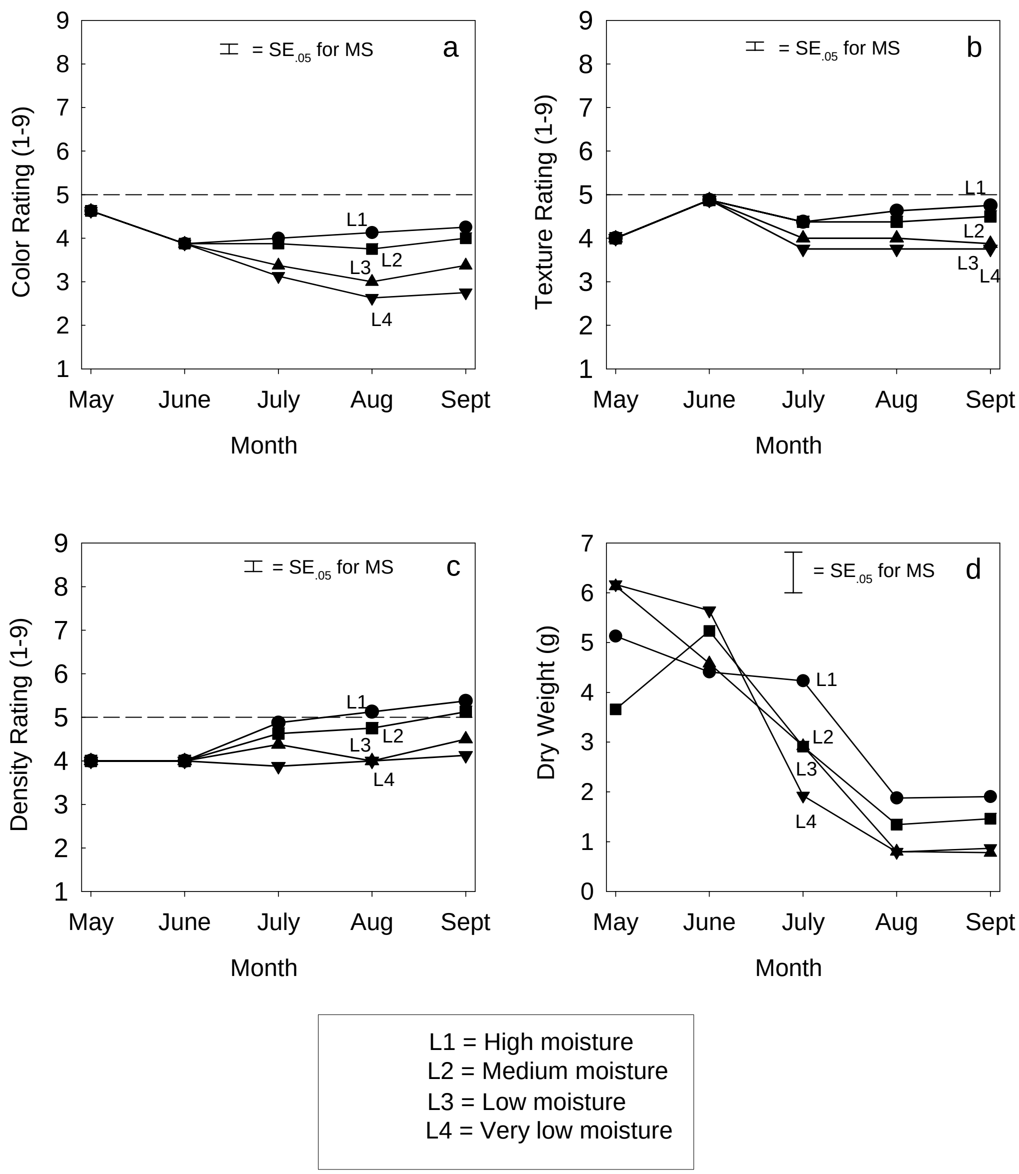

Figure 3.13 Effect of month and moisture level on (a) color (b) texture, (c) density, and (d) dry weight of western wheatgrass + streambank wheatgrass. Color was rated on a 1 to 9 scale with 1 being straw brown and 9 being dark green. Turfgrass texture was rated on a 1 to 9 scale with 1equaling coarse and 9 equaling fine. Density was rated on a 1 to 9 scale with 1 being bare ground and 9 equaling maximum density.

Each point represents a mean of four replicates. Error bars indicate difference of least square means standard error ($p<0.05$) for the M=month main effect, S=subplot main effect, or MS=month x subplot interaction.

subplot dry weight increased significantly in June, when it was not significantly different from the other subplots. A significant drop in weights occurred in July for all subplots except the L1 subplot. In August there was a significant decrease in weights for all subplots except the L4 subplot. All subplots were similar in August and September.

Western Wheatgrass + Streambank Wheatgrass + Sheep Fescue

Color, texture, and density ratings for the western wheatgrass + streambank wheatgrass + sheep fescue mixture all had month by subplot interactions (Figure 3.14a,b,c). Color ratings diverged in August, when the L4 subplot color rating decreased and was significantly lower than the L1 and L2 subplots ratings. In September, the L1 subplot was significantly higher than the L3 and L4 subplots, while the L2 subplot was significantly higher than the L4 subplot.

The texture of the mixture subplots increased significantly from May to June, but decreased in July. There was a significant divergence in textures in August and September. The L4 subplot was significantly lower than other subplots in August and significantly lower than the L1 subplot in September. Although indiscernible by the human eye, densities increased throughout the season. The L1 and L2 subplots were significantly denser than the L3 and L4 subplots from July through September.

Dry weight significant differences for the mixture of western wheatgrass + streambank wheatgrass + sheep fescue were caused by month main effects (Figure 3.14d). Dry weight decreased significantly each month from May to August.

Western Wheatgrass + Streambank Wheatgrass + Sheep Fescue

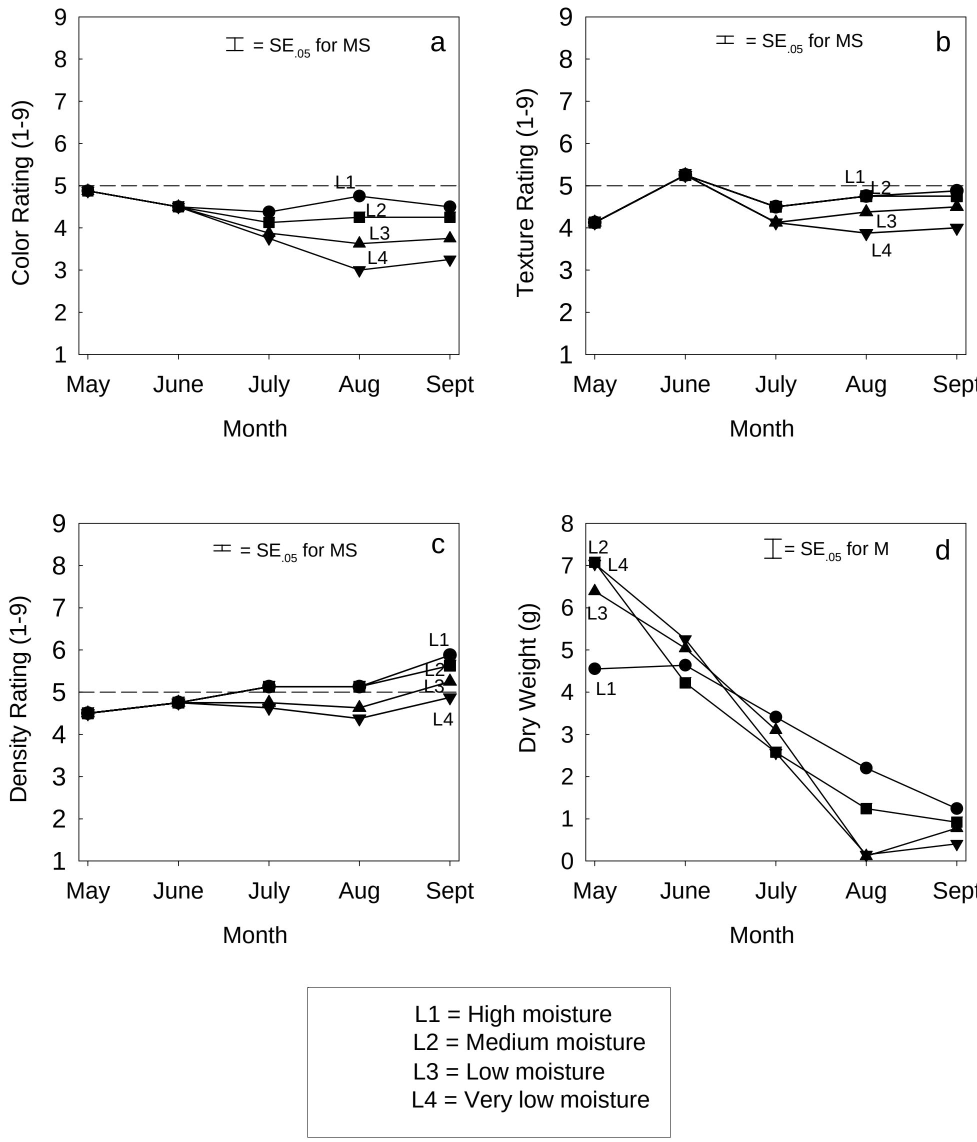

Figure 3.14 Effect of month and moisture level on (a) color (b) texture, (c) density, and (d) dry weight of western wheatgrass + streambank wheatgrass + sheep fescue. Color was rated on a 1 to 9 scale with 1 being straw brown and 9 being dark green. Turfgrass texture was rated on a 1 to 9 scale with 1equaling coarse and 9 equaling fine. Density was rated on a 1 to 9 scale with 1 being bare ground and 9 equaling maximum density. Each point represents a mean of four replicates. Error bars indicate difference of least square means standard error ($p<0.05$) for the M=month main effect, S=subplot main effect, or MS=month x subplot interaction.

Blue Grama + Sandberg Bluegrass

The blue grama + Sandberg bluegrass mixture was not evaluated because of contamination of the Sandberg bluegrass seed stock with a range type tall fescue. The tall fescue overtook the plots making evaluations impossible.

Blue Grama + Western Wheatgrass

Month and subplot main effects were significant for color, texture, and density for the mixture of blue grama + western wheatgrass (Figure 3.15a,b,c). Color ratings increased significantly from May to June, but significantly decreased from June to September. Texture and density ratings increased significantly from May to June, decreased significantly in July, but remained similar from July to September. For color, texture, and density ratings the L1 and L2 subplots were significantly higher than the L3 and L4 subplots.

Dry weight for the mixture of blue grama + western wheatgrass had a significant month main effect (Figure 3.15d) Dry weights significantly increased from May to June, and decreased significantly from June to August.

Buffalograss + Blue Grama + Sandberg Bluegrass

The mixture of buffalograss + blue grama + Sandberg bluegrass was not evaluated because the contaminated Sandberg bluegrass seed stock. A range type tall fescue in the mixture overtook the plots making evaluations impossible.

Buffalograss + Blue Grama + Muttongrass

The buffalograss + blue grama + muttongrass mixture was evaluated even though muttongrass had low vigor and a lack of competition. The mixture gave insight

Blue Grama + Western Wheatgrass

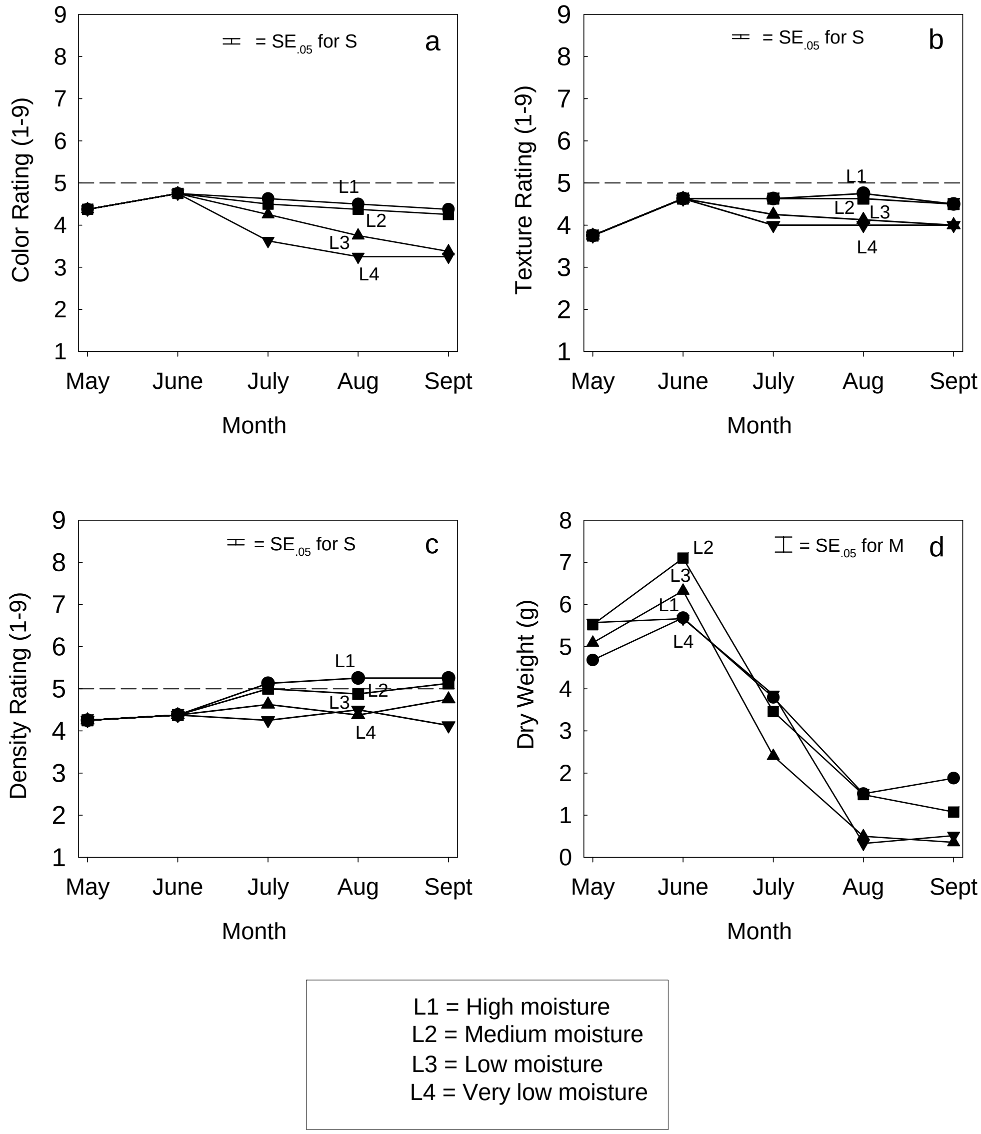

Figure 3.15 Effect of month and moisture level on (a) color (b) texture, (c) density, and (d) dry weight of blue grama + western weheatgrass. Color was rated on a 1 to 9 scale with 1 being straw brown and 9 being dark green. Turfgrass texture was rated on a 1 to 9 scale with 1equaling coarse and 9 equaling fine. Density was rated on a 1 to 9 scale with 1 being bare ground and 9 equaling maximum density.

Each point represents a mean of four replicates. Error bars indicate difference of least square means standard error ($p<0.05$) for the M=month main effect, S=subplot main effect, or MS=month x subplot interaction.

to how the mixture would perform as buffalograss + blue grama. The subplots did not contain the standard 500 PLS per square feet, but did give some understanding about how the mixture would react under differing water measurements.

There was a significant month by subplot interaction for color ratings (Figure 3.16a). All subplots were similar and significantly increased from May to June. The L3 and L4 subplots decreased significantly in July and August, diverging from the L1 and L2 subplots. The L1 and L2 subplots decreased significantly from July to September. In September, the L1 and L2 subplots were significantly higher than only the L4 subplot.

Texture rating significant differences were caused by a month by subplot interaction (Figure 3.16b). The subplots increased significantly from May to June. The L2 subplot decreased significantly in July, while the L3 and L4 subplots significantly decreased in July and then again in August. In August, the L1 and L2 subplots had significantly finer textures than the L3 and L4 subplots. The L1 and L2 subplot texture decreased in September, but was still significantly higher than the L4 subplot.

Density rating differences also were caused by a significant month by subplot interaction (Figure 3.16c). The subplots were similar in May and June. The L1 and L2 subplots increased from June to July and were significantly denser in July than the L3 and L4 subplots. This trend continued until September when the L2 subplot density rating decreased and was significantly less dense than the L1 subplot.

The significant differences in dry weight of the buffalograss + blue grama + muttongrass mixture were caused by month main effects (Figure 3.16d). Dry weight

Buffalograss + Blue Grama + Muttongrass

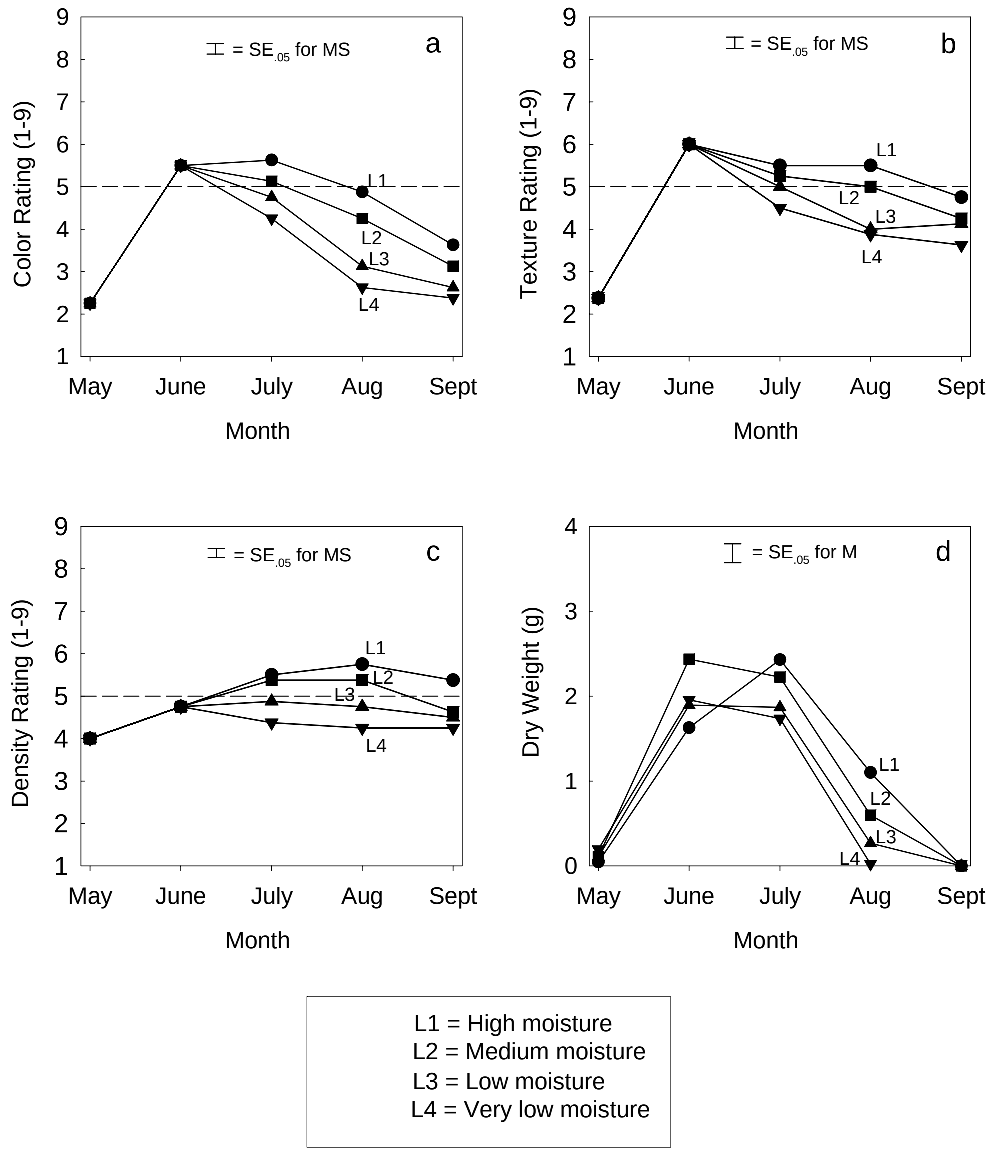

Figure 3.16 Effect of month and moisture level on (a) color (b) texture, (c) density, and (d) dry weight of buffalograss + blue grama + muttongrass. Color was rated on a 1 to 9 scale with 1 being straw brown and 9 being dark green. Turfgrass texture was rated on a 1 to 9 scale with 1equaling coarse and 9 equaling fine. Density was rated on a 1 to 9 scale with 1 being bare ground and 9 equaling maximum density.

Each point represents a mean of four replicates. Error bars indicate difference of least square means standard error ($p<0.05$) for the M=month main effect, S=subplot main effect, or MS=month x subplot interaction.

significantly increased from May to June. From July to September, there was a significant decrease in weights.

Buffalograss _+ Muttongrass

The buffalograss + muttongrass mixture was not evaluated because of muttongrass' low vigor and a lack of competition. Although muttongrass grows well in the greenhouse under manipulated controls, in the field it was poor to establish and was out competed by the buffalograss. This created a situation in which the data collected was similar to the single species of buffalograss.

Buffalograss + Sandberg Bluegrass

The buffalograss + Sandberg bluegrass mixture was not evaluated because of tall fescue contamination in the Sandberg bluegrass seed stock. A range type tall fescue overtook the plots making evaluations impossible.

Buffalograss + Sheep Fescue

Color rating for the buffalograss + sheep fescue mixture had only a significant month main effect (Figure 3.17a). The subplot color rating increased from May to June, but decreased from June to August. Texture rating significant differences were caused by a month by subplot interaction (Figure 3.17b). All subplot color ratings increased significantly from May to June. The L4 subplot color decreased significantly from June to August. In August, the L1 and L2 subplots were significantly higher than the L3 and L4 subplots. By September, only the L4 subplot was significantly less than the L1 and L2 subplots.

Buffalograss + Sheep Fescue

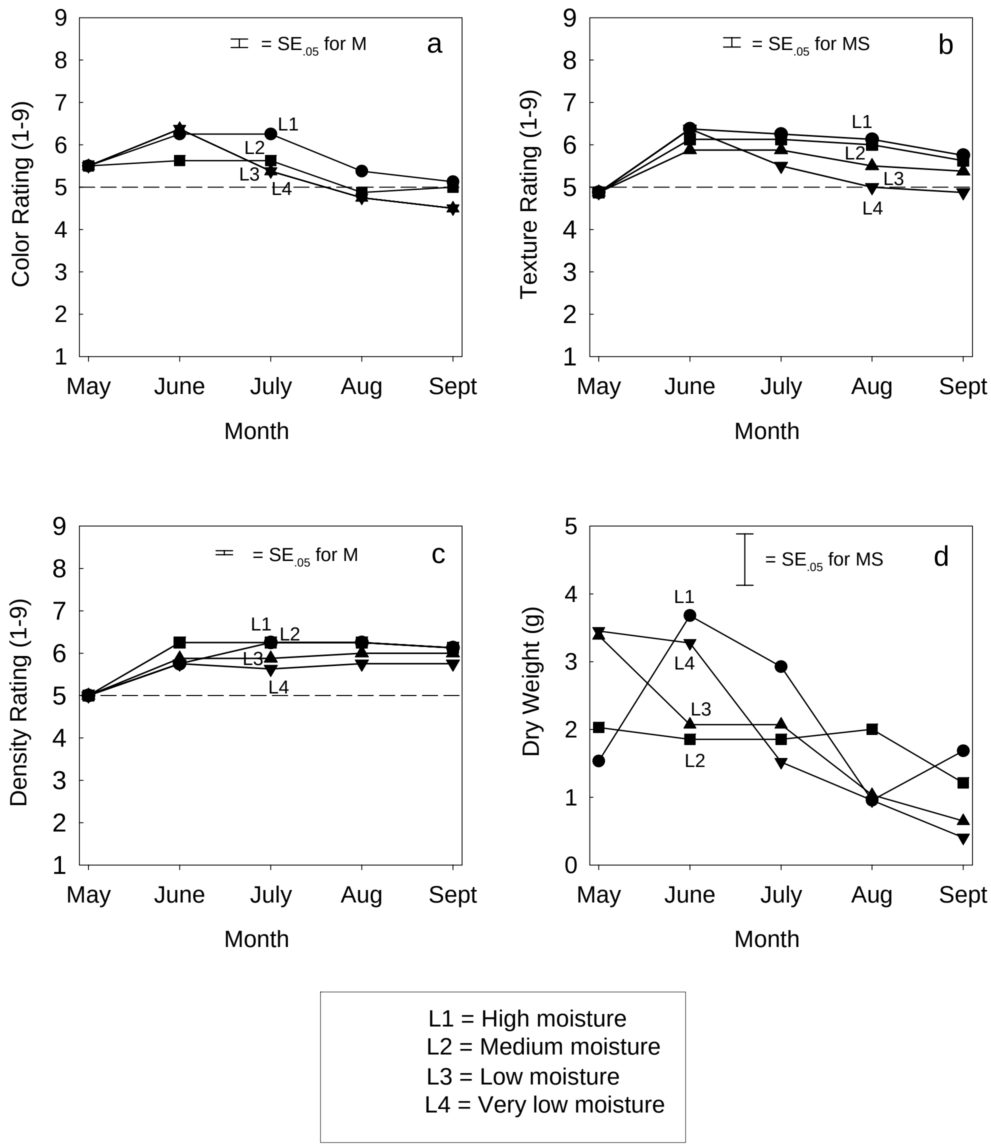

Figure 3.17 Effect of month and moisture level on (a) color (b) texture, (c) density, and (d) dry weight of buffalograss + sheep fescue. Color was rated on a 1 to 9 scale with 1 being straw brown and 9 being dark green. Turfgrass texture was rated on a 1 to 9 scale with 1equaling coarse and 9 equaling fine. Density was rated on a 1 to 9 scale with 1 being bare ground and 9 equaling maximum density.

Each point represents a mean of four replicates. Error bars indicate difference of least square means standard error ($p<0.05$) for the M=month main effect, S=subplot main effect, or MS=month x subplot interaction.

The mixture density had a significant month main effect (Figure 3.17c). The subplot density increased significantly from May to June, then was similar for the remaining months.

Dry weights for the mixture of buffalograss + sheep fescue had a significant month by subplot interaction (Figure 3.17d). In May, the L3 and L4 subplots had higher weight than the L1 and L2 subplots. In June, the L1 subplot increased significantly, while the L3 subplot decreased. The L1 and L4 subplots had significantly higher weights in June than the L3 and L2 subplots. All subplots except the L2 subplot decreased from June to August. In August, all of the subplots were similar. No significant change occurred in dry weights from August to September.

Buffalograss + Western Wheatgrass

There was both a month and a subplot main effect that caused the significant differences in the color of the mixture of buffalograss + western wheatgrass (Figure 3.18a). A significant increase in the color rating occurred from May to June. From June to September, there was a small but significant decrease in the color rating for the buffalograss + western wheatgrass mixture. The L1 subplot color rating was statistically the highest, while the L4 subplot was the lowest.

There was a significant month by subplot interaction for the texture rating of the mixture (Figure 3.18b). The texture of the mixture was significantly finer in May than in June. There was a significant decrease in subplot texture during the remaining months for the L3 and L4 subplots, but they decreased by only one unit.

The month and subplot main effects were significant for the density of the mixture (Figure 3.18c). The density increased significantly in July and remained higher

Buffalograss + Western Wheatgrass

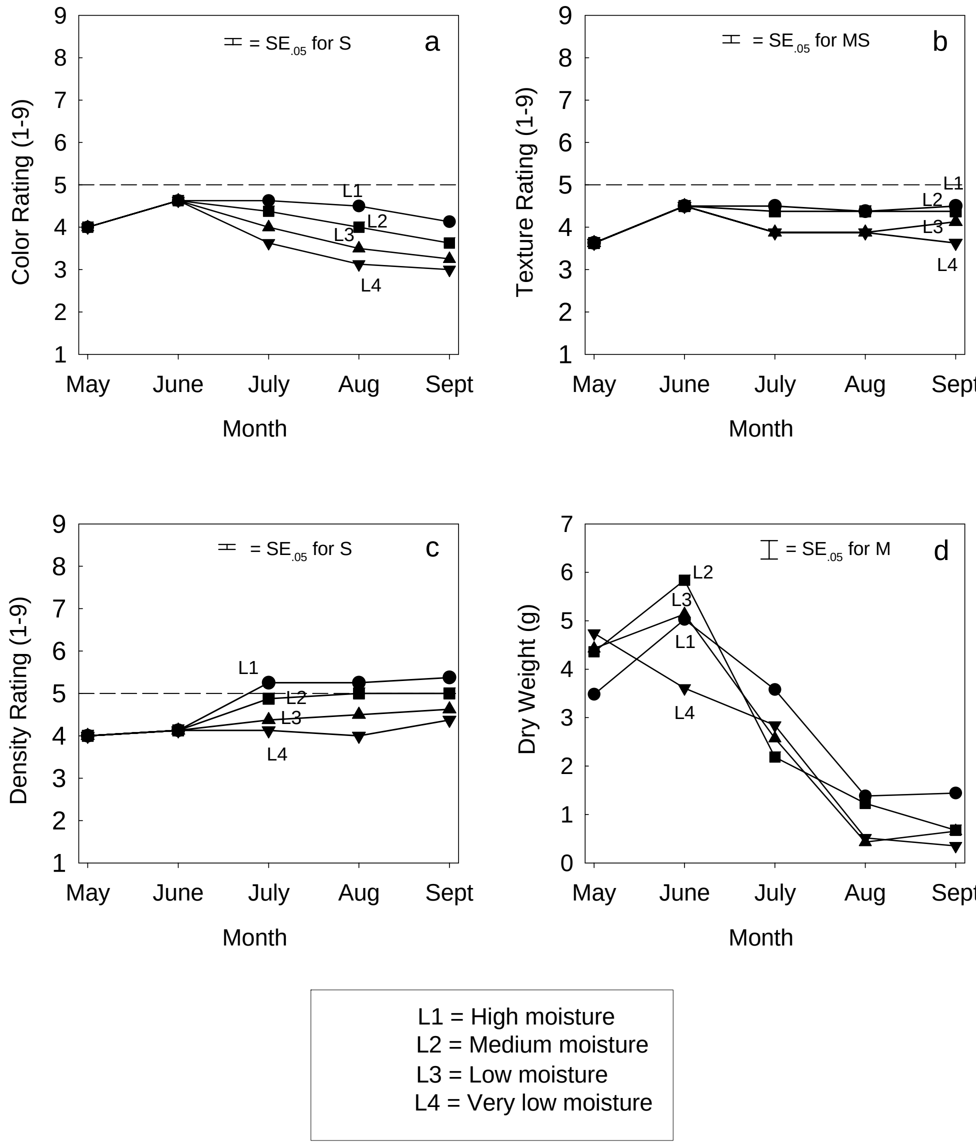

Figure 3.18 Effect of month and moisture level on (a) color (b) texture, (c) density, and (d) dry weight of buffalograss + western wheatgrass. Color was rated on a 1 to 9 scale with 1 being straw brown and 9 being dark green. Turfgrass texture was rated on a 1 to 9 scale with 1equaling coarse and 9 equaling fine. Density was rated on a 1 to 9 scale with 1 being bare ground and 9 equaling maximum density.

Each point represents a mean of four replicates. Error bars indicate difference of least square means standard error ($p<0.05$) for the M=month main effect, S=subplot main effect, or MS=month x subplot interaction.

during August and September. The L1 and L2 subplots were significantly denser than the L3 and L4 subplots.

Month main effects caused the significant differences in dry weight for the buffalograss + western wheatgrass mixture (Figure 3.18d). Dry weights decreased significantly each month from June to August.

Turfgrass Quality

The single species and mixture that had a good overall turf quality were the two introduced grasses of KBG and tall fescue, as well as sheep fescue, blue grama, buffalograss, and the mixture of buffalograss and sheep fescue (Table 3.1). The single specie and mixtures that had adequate overall turfgrass qualities were rated fair. These included the single specie of western wheatgrass and the mixtures of western wheatgrass + streambank wheatgrass, western wheatgrass + streambank wheatgrass + sheep fescue, buffalograss + blue grama + muttongrass, blue grama + western wheatgrass, and buffalograss + western wheatgrass (Table 3.1). Canada bluegrass, crested wheatgrass, streambank wheatgrass, thickspike wheatgrass and the mixtures of Canada bluegrass + crested wheatgrass, and Canada bluegrass + western wheatgrass had poor overall turfgrass ratings and would not be recommended for turfgrass applications in Southwest Montana (Table 3.1).

Water Requirements

The water requirements of KBG, tall fescue, blue grama, and buffalograss for optimum turfgrass quality and basic plant functions increased just as precipitation is declined (Figures 3.19a,b,c and Figure 3.20a). The water requirement for optimum

Table 3.1 Turfgrass Quality and Minimum Weekly Irrigation Recommendations and Timing For Native, Adapted, and Introduced Grasses in Bozeman, Montana

Species or Mix	Overall Turf Color	Overall Turf Texture	Overall Turf Density	Overall Turf Quality	Timing of Turfgrass Color	Recommended Minimum Weekly Irrigation Requirements and Timing for Optimum Turfgrass Quality	Recommended Minimum Weekly Irrigation Requirements and Timing to Retain Some Color
Kentucky bluegrass	good	good	good	good	all season	0.75" mid June to early September	0.75" early July to early September
Tall Fescue	good	fair	good	good	all season	1.00" mid June to early September	1.00" early July to early September
Sheep Fescue	good	good	good	good	all season	0.50" early July to early September	none
Blue Grama	fair	good	good	good	late-May to late- August	0.50" early July to mid August	.50" early-mid July to mid August
Buffalograss	fair	good	good	good	early-June to late- August	0.50" early July to mid August	0.50" early-mid July to mid August
Buffalograss + Sheep Fescue	good	good	good	good	all season	0.50" late-mid July to early September	none
Western Wheatgrass	fair	fair	fair	fair	all season	0.75"late-mid June to early September	only during drought periods
Western Wheatgrass + Streambank Wheatgrass	fair	fair	fair	fair	all season	0.50" late-mid June to early September	only during drought periods
Western Wheatgrass + Streambank Wheatgrass+ Sheep Fescue	fair	fair	fair	fair	all season	0.50" early July to early September	only during drought periods
Blue Grama + Western Wheatgrass	fair	fair	fair	fair	all season	0.50" early-mid July to early September	only during drought periods
Buffalograss + Western Wheatgrass	fair	fair	fair	fair	all season	0.75" early-mid July to early September	only during drought periods
Buffalograss + Blue grama + Muttongrass	fair	fair	fair	fair	early-June to late- August	0.75" mid June to early September	only during drought periods
Canada Bluegrass	poor	poor	fair	poor	all season	0.50" mid June to early September	only during drought periods
Crested Wheatgrass	poor	poor	poor	poor	all season	0.50" mid June to early September	only during drought periods
Streambank Wheatgrass	poor	fair	fair	poor	all season	0.50" mid June to early September	only during drought periods
Thickspike Wheatgrass	poor	fair	fair	poor	all season	0.50"early July to early September	only during drought periods
Canada Bluegrass + Crested Wheatgrass	poor	poor	fair	poor	all season	0.50" mid June to early September	only during drought periods
Canada Bluegrass + Western Wheatgrass	poor	fair	fair	poor	all season	0.50" mid June to early September	only during drought periods

turfgrass quality of sheep fescue increased similarly, but basic plant function water demands remained lower than the average weekly precipitation for Bozeman, Montana (Figure 3.20b). The buffalograss + sheep fescue mixture also increased in moisture requirements, but the need for water for the mixture was much later in the year compared to the other single species and mixtures in the study (Figure 3.20c). The moisture needed to retain the basic plant functions of the buffalograss + sheep fescue mixture remained lower than the average weekly precipitation for Bozeman, Montana.

The water requirements for optimum turfgrass quality for western wheatgrass, and the mixtures of buffalograss + blue grama + muttongrass, blue grama + western wheatgrass, buffalograss + western wheatgrass, western wheatgrass + streambank wheatgrass, and western wheatgrass + streambank wheatgrass + sheep fescue all increased as precipitation declined (Figure 3.21a,b,c and Figure 3.22a,b,c). However, to retain only plant functions, these species and mixtures required supplemental irrigation only during drought periods. Although the water requirements of these grasses and mixtures were similar to that of KBG and tall fescue, their color, texture, and density ratings were lower and were considered to be adequate for turfgrass applications.

Thickspike wheatgrass, Canada bluegrass, crested wheatgrass, streambank wheatgrass, and the mixtures of Canada bluegrass + western wheatgrass, and Canada bluegrass + crested wheatgrass all had very similar water requirements (Figure 3.23a,b,c and Figure 3.24a,b,c) Water requirements for these species and mixtures ramped up as average precipitation declined. The water requirement to retain basic plant functions for these single species and mixtures were all lower than the average precipitation for Bozeman, Montana, and therefore needed irrigation only during drought periods. Water requirements for this group were also similar to KBG and tall fescue, but as stated earlier, they were poor candidates for turfgrass applications.

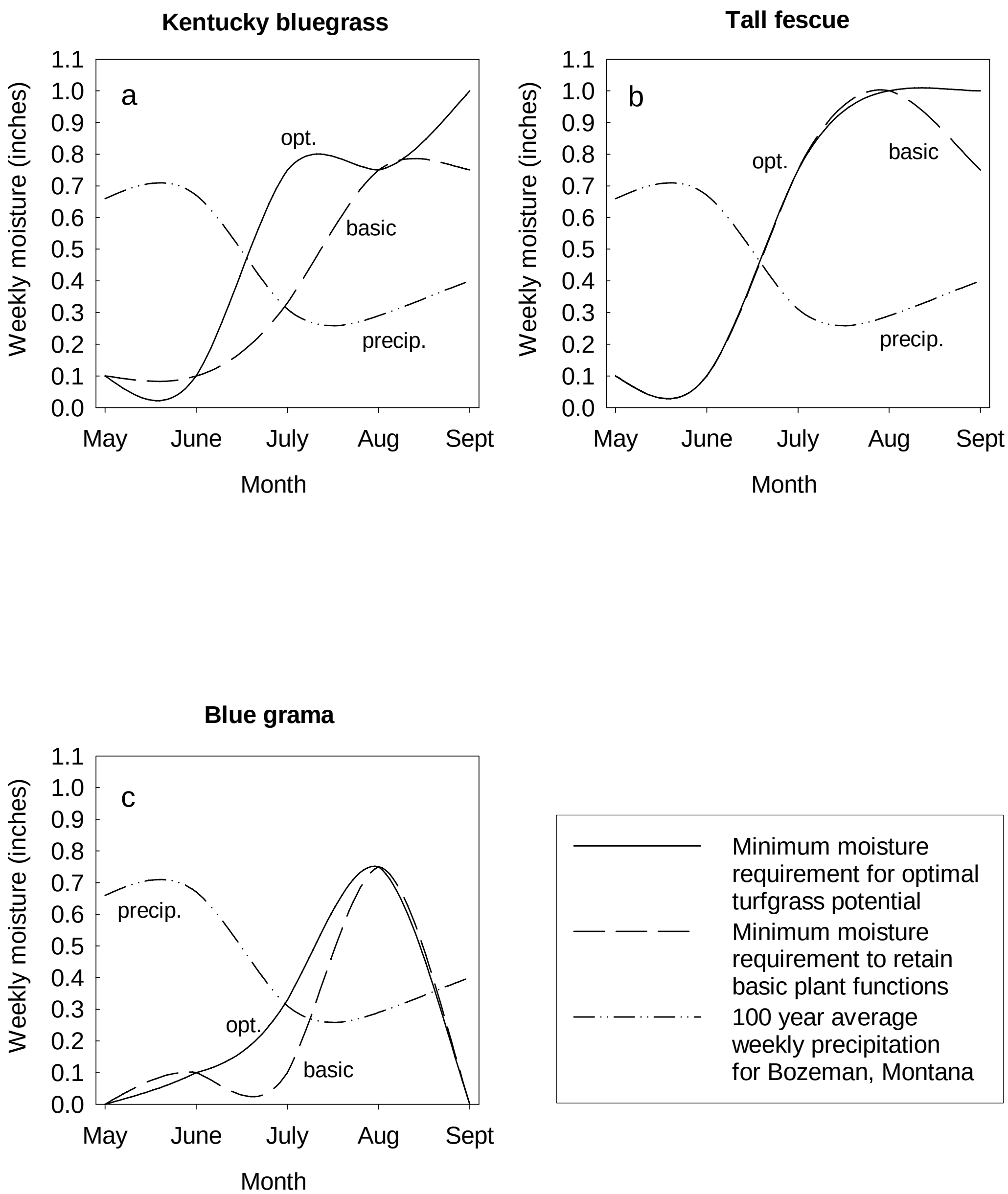

Figure 3.19 Minimum irrigation moisture requirements for optimum turfgrass quality and to retain basic turfgrass functions for (a) Kentucky bluegrass, (b) tall fescue, and (c) blue grama and 100 year average weekly precipitation for Bozeman, Montana.

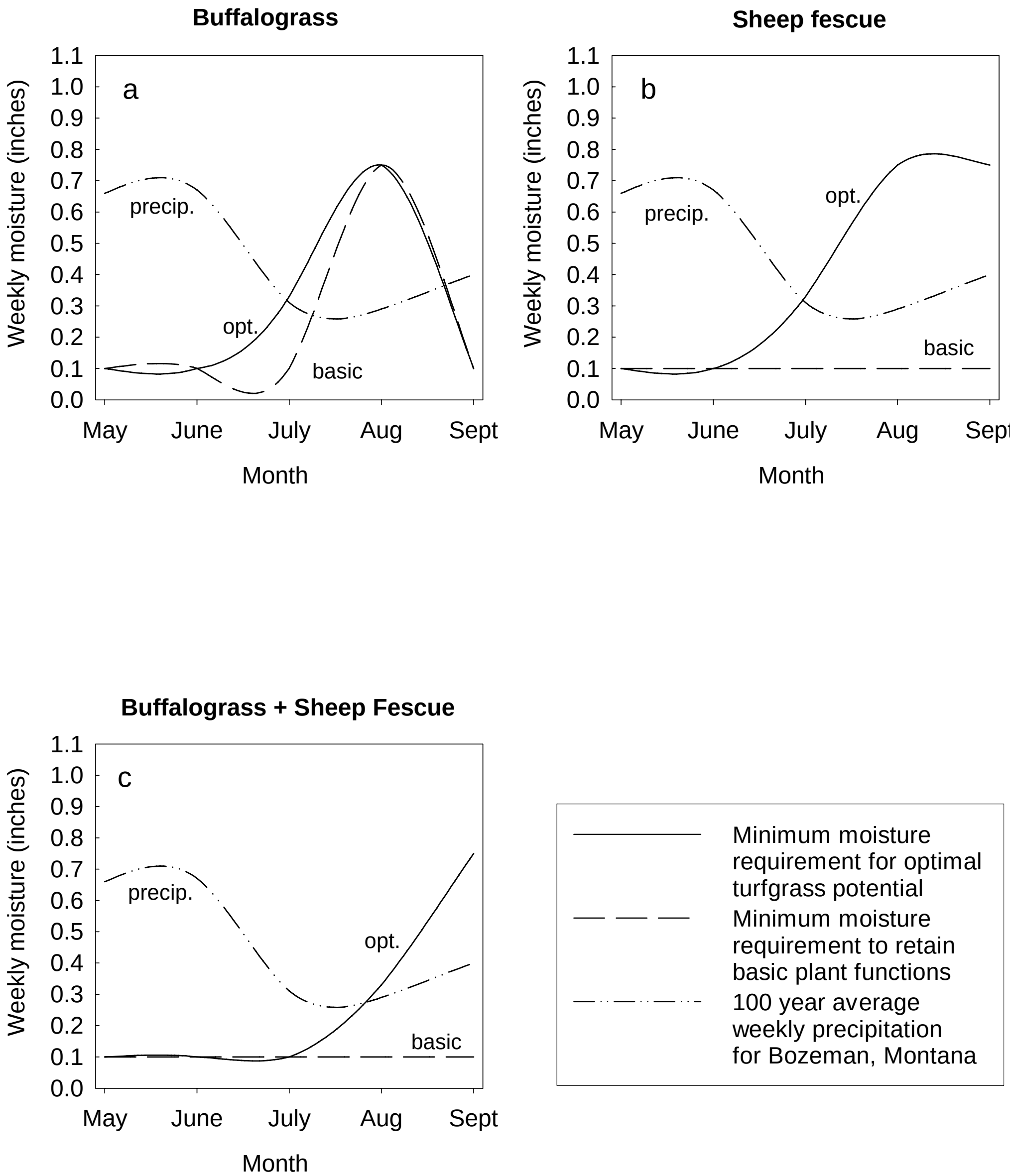

Figure 3.20 Minimum irrigation moisture requirements for optimum turfgrass quality and to retain basic turfgrass functions for (a) buffalograss, (b) sheep fescue, and (c) buffalograss + sheep fescue and 100 year average weekly precipitation for Bozeman, Montana.

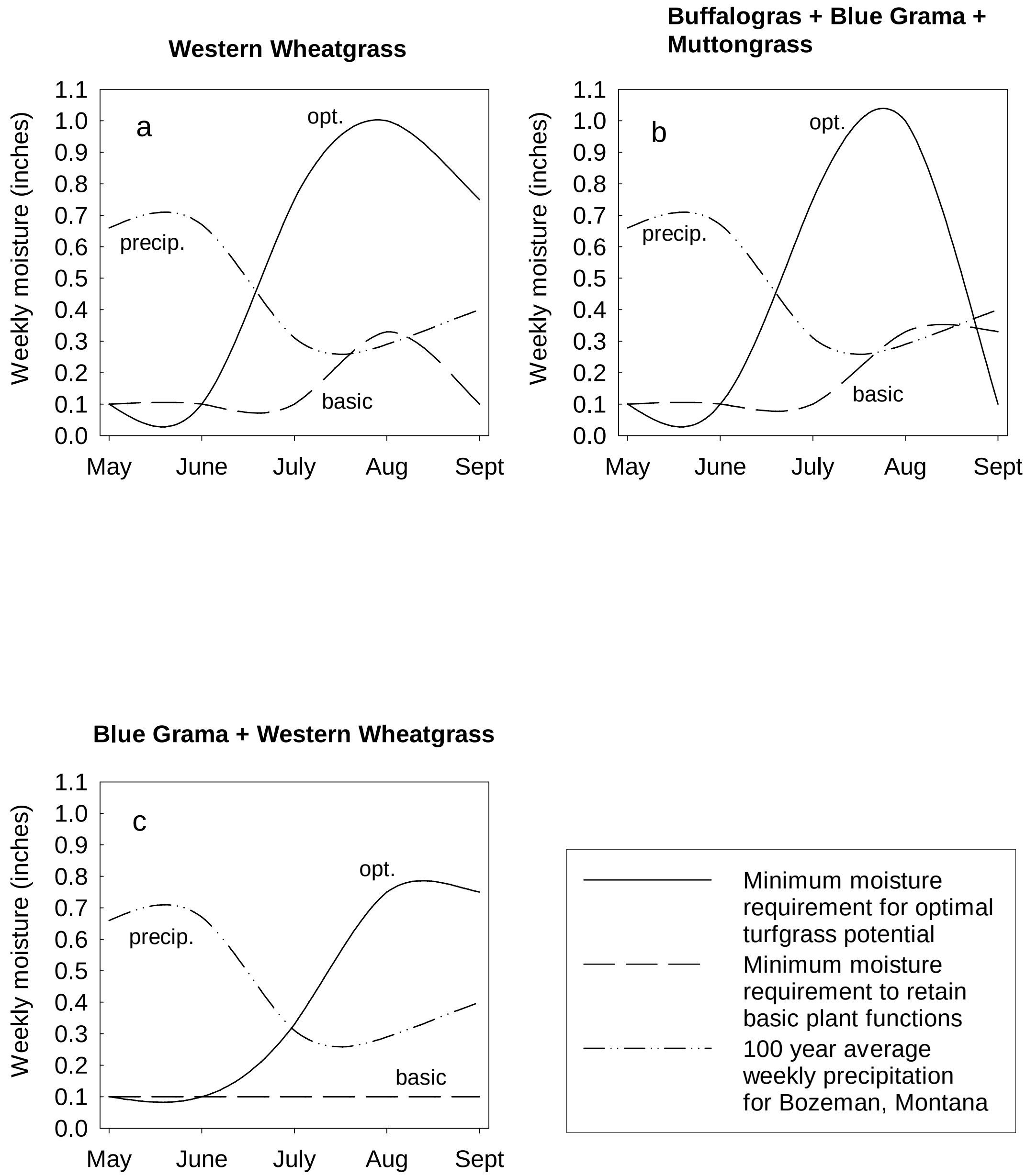

Figure 3.21 Minimum irrigation moisture requirements for optimum turfgrass quality and to retain basic turfgrass functions for (a) western wheatgrass, (b) buffalograss + blue grama + muttongrass, and (c) blue grama + western wheatgrass and 100 year average weekly precipitation for Bozeman, Montana.

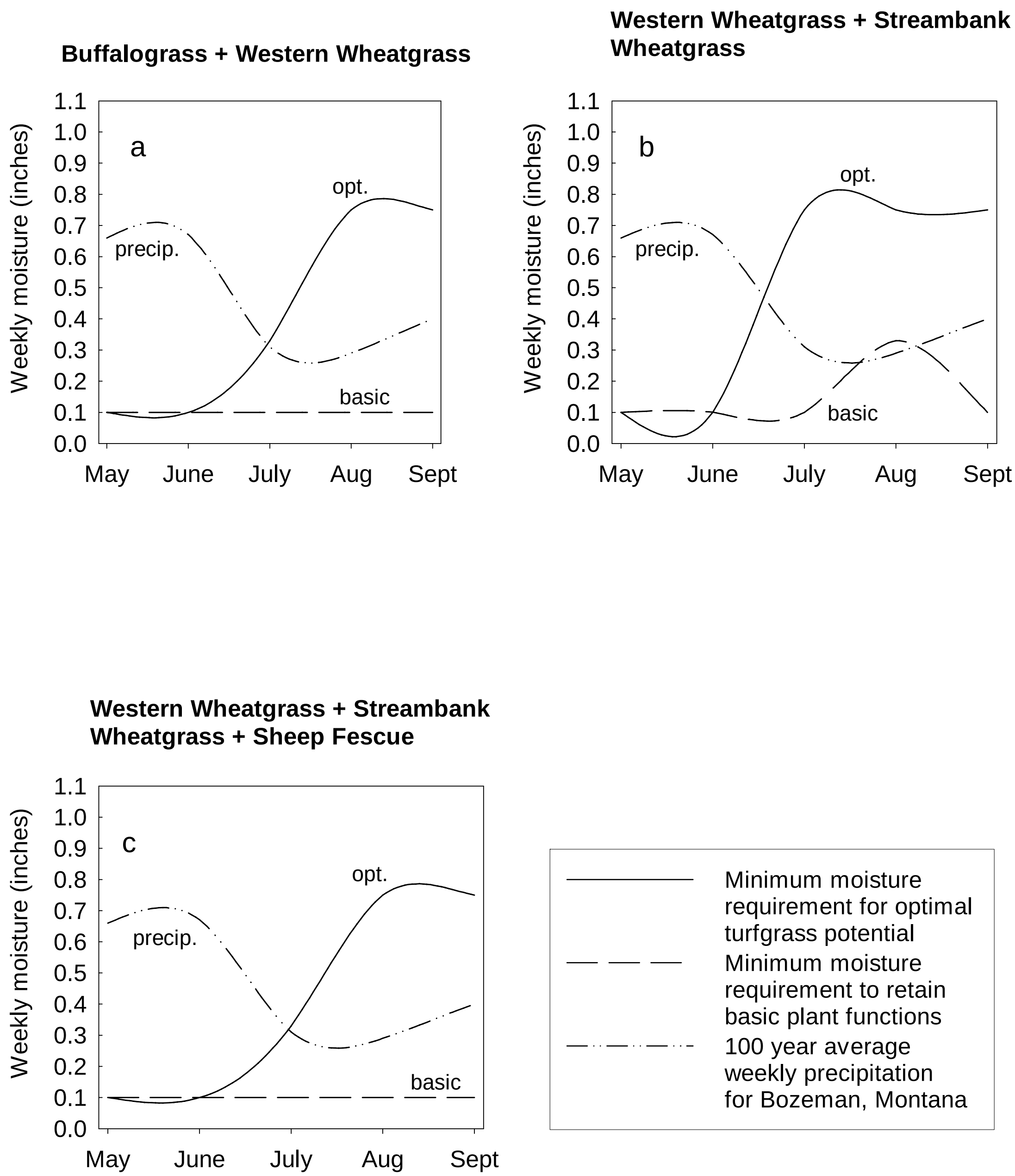

Figure 3.22 Minimum irrigation moisture requirements for optimum turfgrass quality and to retain basic turfgrass functions for (a) buffalograss + wesstern wheatgrass, (b) western wheatgrass + streambank wheatgrass, and (c) western wheatgrass + streambank wheatgrass + sheep fescue and 100 year average weekly precipitation for Bozeman, Montana.

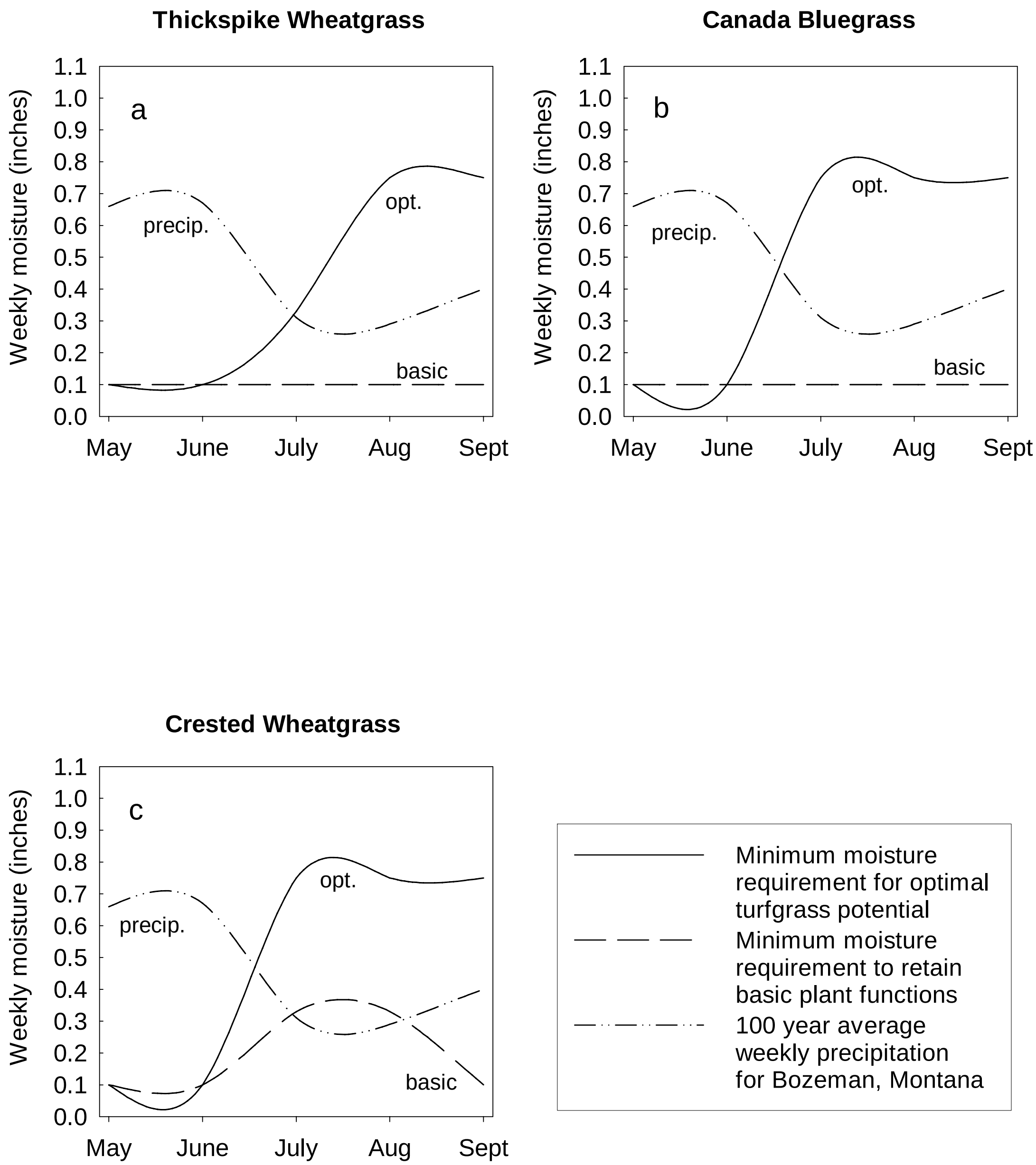

Figure 3.23 Minimum irrigation moisture requirements for optimum turfgrass quality and to retain basic turfgrass functions for (a) thickspike wheatgrass, (b) Canada bluegrass, and (c) crested wheatgrass and 100 year average weekly precipitation for Bozeman, Montana.

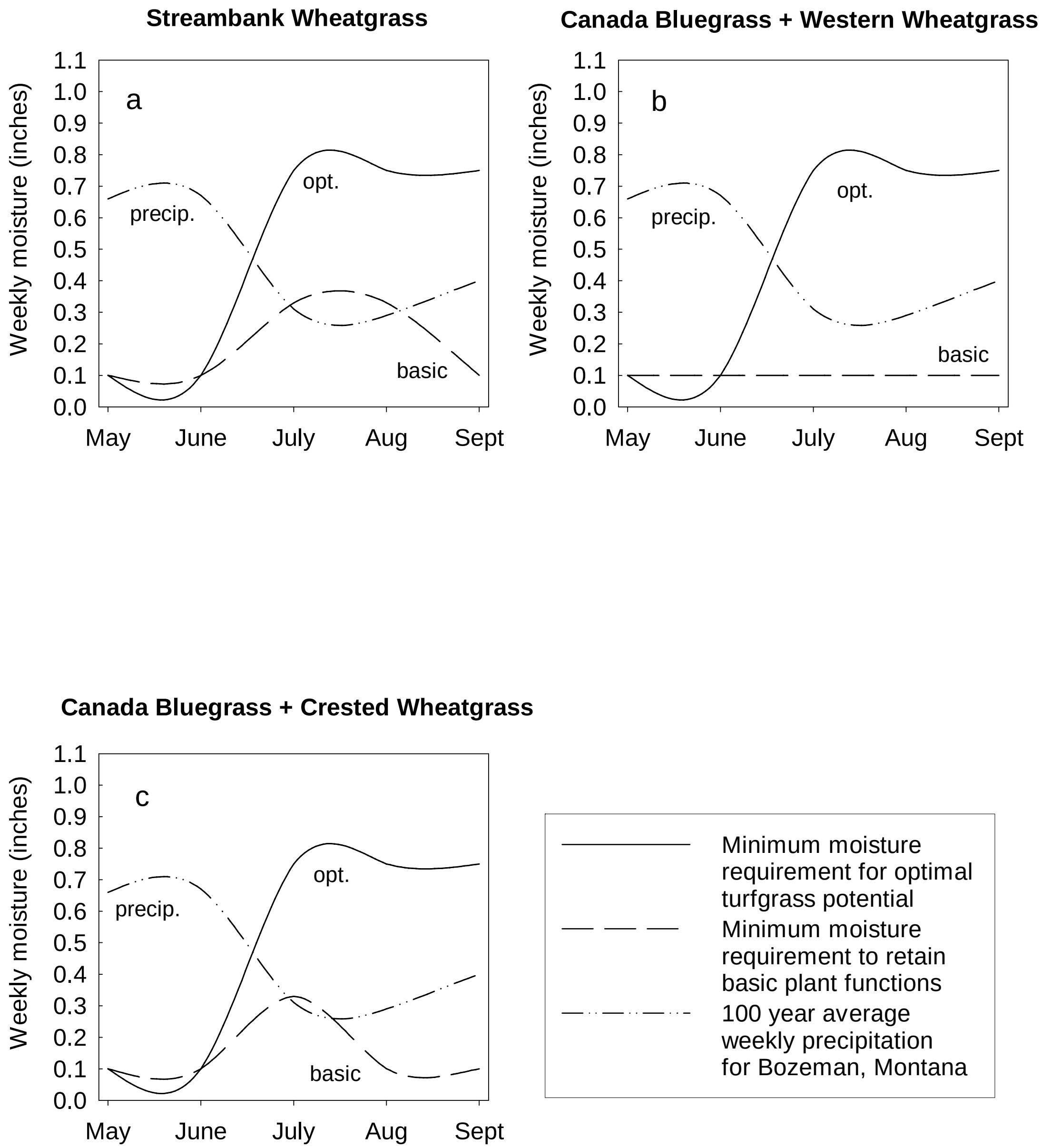

Figure 3.24 Minimum irrigation moisture requirements for optimum turfgrass quality and to retain basic turfgrass functions for (a) streambank wheatgrass, (b) Canada bluegrass + western wheatgrass, and (c) Canada bluegrass + crested wheatgrass and 100 year average weekly precipitation for Bozeman, Montana.

DISCUSSION AND CONCLUSION

Hypothesis 1: Native and adapted grasses will hold their desired turfgrass qualities under low water conditions.

KBG and tall fescue's color, texture, and density significantly decreased under low water conditions. The high and medium moisture subplots held the turfgrasses expected color, texture, and density, which proved that if the optimum turfgrass qualities are desired, irrigation will have to occur at an average rate of three-quarters to one inch of precipitation a week. Tall fescue required more water than KBG to retain its turfgrass qualities.

Sheep fescue was the only monostand of grass that had overall better turfgrass qualities under low water conditions than KBG and tall fescue. It held its color and texture under low moisture in the arid months of July, August, and September when it was subjected to 0.33 inches of moisture or less. During those same months, within the same low moisture environment, KBG and tall fescue lost substantial color and texture.

Sheep fescue has a fine texture that gives it an advantage over the wide blade of tall fescue. Sheep fescue had similar texture ratings compared to KBG, rating above the accepted level of five when subjected to higher moisture. When moisture was limited, the texture of sheep fescue did not decrease as substantially as KBG in the drier months of July, August, and September.

The density of these three grasses, when subjected to higher moisture amounts, had ratings greater than the accepted rating of five. In the lower water regimes, tall fescue density ratings dropped below acceptable densities in July, August, and September. Lower moisture caused the density of sheep fescue and KBG to decline in July. However, sheep fescue density increased in September, while the KBG densities did not. Both KBG and sheep fescue densities remained above the acceptable level throughout the season under low water.

The appearance and overall turfgrass quality of sheep fescue makes it a respectable replacement for conventional turfgrasses in landscapes that require less moisture. The fine texture and dark green appearance of sheep fescue held better than the conventional turfgrass under low moisture and its density did not decrease. More research is needed on sheep fescue to determine its compatibility to other environments.

Many grasses held their color, textures, and densities well enough to be considered acceptable turfgrasses for low water conditions. With some supplemental irrigation at key times, some native and adapted turfgrass will perform well and could be accepted as alternatives to KBG or tall fescue. For instance, western wheatgrass did not score well using NTEP scoring, but it held its color, texture, and density for the season with supplemental irrigation. This does not mean that a lawn planted with these grasses or mixtures will have the same appearance as KBG, but they may have applications in drought tolerant landscapes. Furthermore, many of the plots containing western wheatgrass had a lighter blue-green appearance and may compliment the color palette of drought tolerant landscape designs.

Other grasses held their color, texture, or density, but made for a poor turfgrass. For example, crested wheatgrass held its color, texture, and density, but the brown-green color and overall low densities of crested wheatgrass made it undesirable for turfgrass. Crested wheatgrass may only be a good candidate for functional use, such as erosion control and slope stabilization.

Thickspike wheatgrass and streambank wheatgrass are other grasses that had some desirable turfgrass characteristics, but shredded when they were mowed. They produced a fine texture and formed a dense turf, but the shredding caused a white cast over the turf, thus making it undesirable.

Canada bluegrass appeared to have good turfgrass quality only in the early spring. It held fair density throughout the season, but repeated mowing decreased its color and texture, thus making it a poor choice for turfgrass applications.

Hypothesis 2: Mixtures of the adapted and native grasses will hold their desired turfgrass qualities under low water conditions.

The warm-season/cool-season mixtures of buffalograss and western wheatgrass, blue grama and western wheatgrass, and buffalograss and sheep fescue had overall color, texture and density scores that were more consistent throughout the growing season when compared to the single species of buffalograss or blue grama. Buffalograss and blue grama are C4 grasses with late greenup and early fall dormancy that contribute to low color and texture ratings in the spring and fall. When C3 grasses such as western wheatgrass or sheep fescue were added to the warm-season grass mixture, an early spring and late fall flush of color and texture enhanced color and texture scores. Conversely, the addition of the warm-season grasses to western wheatgrass or sheep fescue did not detract form the overall turfgrass qualities of the western wheatgrass or the sheep fescue. Although blue grama or buffalograss had altered the appearance of either western wheatgrass or sheep fescue stands, the color and texture ratings still remained consistently at or near the same level.

It is then recommended that if one was to select a warm-season grass for turfgrass in cooler climates like Southwest Montana, an addition of a cool-season grass would increase desired turfgrass qualities with more consistency throughout the growing season. However, compatibility studies should be performed to see if species dominance occurs.

There was no correlation as to whether there was an increase in performance when a mixture contained only cool-season grasses or only warm-season grasses. Every cool season mixture in this study contained a species, such as crested wheatgrass, Canada bluegrass, or streambank wheatgrass, which was considered undesirable for turfgrass use. There was a limited increase in turfgrass quality by other species masking their negative attributes, but the overall increase was not convincing enough to recommend the mixture.

In some cases, such as the western wheatgrass, streambank wheatgrass, and sheep fescue mix, the addition of the wheatgrasses to the sheep fescue reduced the overall turfgrass scores as it was planted as a single species. If two higher-quality, cool-season native and adapted grass species were isolated for their turfgrass use, it would be applicable to retry this study. Until then, the mixing of the cool-season grasses in this study is not advisable.

The buffalograss, blue grama, and muttongrass mixture did not have better turfgrass qualities than the single species of buffalograss and blue grama. Therefore, one would only need to mix the two warm-season grasses if specific colors or textures were desired.

Hypothesis 3: Native and adapted grasses and their mixtures will retain their desirable turfgrass qualities while requiring less water than Kentucky bluegrass and tall fescue.

No grass species or mixture could perform optimally without supplemental irrigation in Bozeman, Montana. Sheep fescue, blue grama, buffalograss, and the buffalograss and sheep fescue mix required less supplemental irrigation than KBG and tall fescue. However, to sustain acceptable growth, sheep fescue and the buffalograss and sheep fescue mix could do without supplemental irrigation.

Many of the grasses and mixtures required less minimum moisture and had a later recommended timing for irrigation than KBG. Many grasses could withstand drought and on average would only need minimal amounts of water to retain plant functions.

Turfgrass Recommendations for Bozeman, Montana

The grasses and mixtures with overall ratings above the acceptable score of 5 for color, texture, and density are considered the best candidates for turfgrass. They include the buffalograss + sheep fescue mix, sheep fescue, blue grama, and buffalograss. These grasses and mixtures would be acceptable in areas where overall aesthetics is desired and limited water resources prohibit using KBG.

Buffalograss + Sheep Fescue Mixture

The buffalograss and sheep fescue mixture had the best overall turfgrass quality of all of the native and adapted grasses and mixtures. The turfgrass color was above acceptable levels without supplemental irrigation in May, June, and July. In August and September, only minimal amount of moisture was needed to retain an acceptable color. The minimum irrigation requirement for the buffalograss and sheep fescue mix was one-third to one-half the moisture required for KBG and tall fescue. The buffalograss and sheep fescue mix only required a minimum weekly irrigation of 0.50 inches and was recommended to begin the third week of July to obtain optimum turfgrass quality. This was more than five weeks later than the recommended timing of irrigation for the controls.

The texture for the mixture of buffalograss + sheep fescue also remained above the acceptable level for all subplots during all months. The finer leaf blade of sheep fescue combined with the fine texture of buffalograss provided a textured turfgrass that only diminished slightly with lower water amounts in the later months of the season.

The mixture produced a thick mat of grass which was confirmed by a high density score for all months and water regimes. Buffalograss + sheep fescue had a density equaling that of the sheep fescue, filling in with no bare patches and very little weed penetration. This was unexpected because the single species of buffalograss had only fair densities, especially within the lower moisture subplots.

The high color ratings of the buffalograss + sheep fescue mixture confirmed the hypothesis that a warm season grass combined with a cool season grass would support color throughout the season. Color ratings, with supplemental irrigation, were above acceptable levels in August and September. These are months when buffalograss has significant loss of color because of dormancy. The dark green color of sheep fescue appeared to mask the brown dormant color of buffalograss in the spring and the fall.

The stoloniferous growth habit of the buffalograss combined with the bunch-type growth habit of sheep fescue could make the mixture a good candidate for sod production. Weekly mowing did not suppress stolon growth for buffalograss and allowed it to fill in areas where seeds were not dispersed well in initial seeding. Sheep fescue filled in very well and appeared to have good binding qualities within its root zone.

There are two possible explanations why the mix did so well. First, a better distribution of the root system throughout the soil profile would mean there is less competition for available moisture. Buffalograss is a C4 plant and has a maximum root depth that is much deeper than the C3 sheep fescue. This distribution of root mass throughout the soil profile allows sheep fescue to use the available moisture in the upper soil profile with less competition. The ability of buffalograss to take up moisture from lower in the soil profile with less competition means it could sustain plant functions, thus retaining its positive turfgrass qualities. Second, there was less competition for soil moisture within the root zone. The seeding rate for all the plots was 500 PLS per square feet. In the mixtures, the seeding rate was split among the species. This meant that approximately half the number of plants within the specific root zone was competing for the available water.

A drawback to the mixture is that it did not appear to be able to withstand the foot traffic based on daily observations and weekly mowing records. The foot traffic caused the grasses in the mixture to lie over, suggesting that the mixture may not be able to withstand wear. Wear resistance would be important in areas such as athletic fields and parks or in yards where increased traffic may occur from children, pets, or recreational activities.

Sheep Fescue

Sheep fescue's fine texture and dark green color contributed to its overall turfgrass quality, making it a good candidate for a drought tolerant turfgrass. Although it required some late-season irrigation to retain its color and texture, it held favorable color for the entire season. Sheep fescue also provided high densities when planted at 500 PLS per square feet.

Less irrigation and a later application of irrigation reinforces the recommendation that sheep fescue could be used as a drought tolerant turfgrass. The recommended minimum water requirements and timing for optimum quality of sheep fescue was 0.50 inches starting July 1. Sheep fescue required one-third to one-half the amounts of average supplemental irrigation needed for KBG and tall fescue and a two-week later irrigation timing.

Sheep fescue also could be considered for a low-maintenance turfgrass because it doesn't require mowing on a weekly basis. Sheep fescue has a maximum height of six inches. It grew only moderately in May and June, and dry weights were low from July to September. Because of its short stature and moderate growth, mowing frequency is reduced and may only be needed earlier in the season.

A definite disadvantage to sheep fescue is that it did not hold up well to foot traffic, similar to the buffalograss and sheep fescue mixture. Wear tolerance studies, as well as mowing rate and timing, weed competition, disease and pest tolerance, and fertility studies should be performed before it is truly considered a low-maintenance turfgrass.

Blue Grama and Buffalograss

The two warm-season grasses, blue grama and buffalograss also performed well, with high color, texture, and density ratings in the summer months. Warm-season grasses such as blue grama and buffalograss have a late green-up and an early dormancy. However, mid-summer color ratings were above acceptable. The color ratings for these grasses were acceptable during June, July, and August, but increased water was needed in August to retain acceptable color. Plant texture and densities in both species were also acceptable, but were dependent on supplemental moisture during the growing period.

An attracting quality to these warm-season grasses is that average supplemental irrigation would only need to occur for six to seven weeks for optimum turfgrass quality compared to eleven to twelve weeks of irrigation for KBG and tall fescue. A minimum weekly irrigation of 0.50 inches from July 1 to August 15 is recommended for these warm-season grasses for their optimum turfgrass quality in this region. Supplemental irrigation is one-third to one-half the recommended rate of KBG and tall fescue and has a two-week later timing than the traditional turfgrasses. There would be a three- to four-fold water savings for the summer if these warm-season grasses were used compared to conventional turf. There may be a less favorable timing of color, but blue grama and buffalograss may be suitable for regions with warmer springs and falls or for people who want only summer color.

Small differences between blue grama and buffalograss may favor choosing one of the species over another. Blue grama greened-up earlier in the spring and was a lighter green compared to the light blue-green of buffalograss. Texture and density of blue grama also appeared to be better early in the season compared to the buffalograss. Buffalograss, on the other hand, is stoloniferous and may have a better recuperative capacity if there is a disturbance. Buffalograss also appeared to be able to withstand long periods of moisture, while the blue grama discolored when waterlogged during rain periods which lasted for several days.

As with the sheep fescue and buffalograss + sheep fescue mixture, there should be further research to determine suitability of the buffalograss + blue grama mixture for turfgrass. One concern is their ability to withstand winterkill. Although they survived the winter in this experiment, much harder winters have been known to occur. The warm-season grasses should be further evaluated in cooler regions such as Bozeman, Montana.

Turfgrass Quality of KBG and Tall Fescue

Most of the turfgrass in the Intermountain West contains KBG. KBG is planted because it has desired turfgrass qualities such as good color and texture, high densities, wear resistance, and good recuperative capacities. However, the retention of these qualities requires high amounts of moisture.

KBG was indeed dependent on higher moisture for long periods of time to achieve overall turfgrass quality. It had the desirable kelly green color, but was unable to hold that color from July to September without increased amounts of moisture.

The turfgrass industry recommends that KBG receive an inch of water every week for optimum turfgrass quality. The results of this experiment confirmed this with a recommendation of a minimum of 0.75 inches and an optimum 1.00 inches of water per week, starting in mid-June to retain optimum color. Starting irrigation in July, any water less than 0.75 inches per week caused the grass to go dormant and turn brown.

Color was not the only parameter affected with low irrigation amounts. Texture ratings of KBG were also lowered at a minimum irrigation of 0.75 inches per week in the later half of the season.

Tall fescue is a rough-textured turfgrass that has many good attributes, such as good color and density desired for turfgrass. However, it is mainly used on athletic fields because of its wear resistance. Recently, tall fescue seed has been marketed as a drought tolerant turfgrass because of its deep root growth. According to the results of this study, to retain the desired turfgrass qualities tall fescue required just as much water as KBG, if not more. Tall fescue required a <u>minimum</u> of 1.00 inch of irrigation per week starting mid-June to retain acceptable color ratings. This is counterintuitive to the anecdotal evidence that tall fescue is as drought tolerant as KBG.

Further evidence that tall fescue may not be suitable as a drought tolerant turfgrass is that the texture rating fell below the acceptable level for the season, as expected, because of the wide leaf blade. Plot densities were acceptable, although water amounts below 0.75 inches in August and September decreased plant densities for tall fescue.

<u>Turfgrass Recommended for Low-Maintenance Turf</u>

Some species and mixtures lent themselves to be adequate drought tolerant turfgrass, but lack either the color, texture, density, or a combination of characteristics that would make them favorable for optimal turfgrass purposes. In this study, many of the results for color, texture, and density for these plots may have fallen below the acceptable level of 5, but held ratings just below that benchmark for most of the season.   In most cases, the grasses or mixtures adequate for drought tolerant turfgrass needed supplemental water to achieve optimum appearance.

Western Wheatgrass

The light green-blue appearance and drought tolerant attributes of western wheatgrass could make it an alternative turfgrass in drought tolerant landscapes. It is not expected that any of the wheatgrasses would appear to have the same optimal characteristics as the controls, but some attributes of western wheatgrass may be desirable. Its color, texture, and density ratings were just below 5, but they were mostly consistent throughout the season. Optimum ratings for western wheatgrass did require higher moisture levels from July to September. However, if less water was applied, the reduction in its qualities would be minimal except for color. To retain the desired color of western wheatgrass, 0.75 inches per week of irrigation would have to occur.

Western wheatgrass had fair color, texture, and density ratings, but required a minimum of 0.75 inches of supplemental irrigation starting the third week in June to retain optimum color. When western wheatgrass was added to a mixture, the need for supplemental irrigation decreased and the irrigation time was delayed accordingly. Further study and possible selection of differing races of western wheatgrass may make it applicable for drought resistant turfgrass in other regions of the Intermountain West.

Western Wheatgrass Mixtures

The mixture of western + streambank wheatgrass and the mixture of western wheatgrass + streambank wheatgrass + sheep fescue had very similar color, texture, and density ratings. Both mixtures held their color for the season, but some minimum irrigation later in the season was required for optimum turfgrass appearance. When the others species were added to western wheatgrass, 0.25 inches less moisture was required than when western wheatgrass stood alone. Most of the ratings for texture were just below the acceptable level because wheatgrasses have wider blades and higher meristematic regions that make them appear to be less dense. Densities also were just below the accepted level, but increased with supplemental irrigation.

Minimum water required for optimum color, texture and density in the western wheatgrass and streambank wheatgrass mixture was 0.50 inches per week from mid July to early September. When sheep fescue was added to the mixture, 0.50 inches was the minimum moisture requirement, but supplemental irrigation could begin on average a week later. The supplemental irrigation requirements were one-quarter to one-half the recommended rates for KBG and tall fescue. Furthermore, the estimated timing of irrigation in a sheep fescue mixture was one to two weeks later than timing of irrigation for KBG and tall fescue. This would equate to a substantial decrease in overall water use.

The streambank wheatgrass in the mixture lowered ratings for color because it shreds when mowed. Shredding formed a white cast on the plots making them appear less desirable. Interestingly, in the western wheatgrass, streambank wheatgrass, and sheep fescue colors did not mix well and gave the mixture a mottled effect of light tan, dark green, and light blue-green. This mixture was affectionately called “camograss.”

When western wheatgrass was mixed with the warm-season grasses of blue grama and buffalograss, the color, texture, and density ratings held at or just below the acceptable score of 5, which meant that these mixtures, although not optimum, may be good candidates for drought tolerant turfgrass. Furthermore, these mixtures fit well with the desired mixing of a warm-season with a cool-season grass, and mixing a stoloniferous growth habit with a bunch type growth habit as in the buffalograss and western wheatgrass mixture.

The timing of supplemental irrigation for the buffalograss or blue grama + western wheatgrass mixture was delayed until early July. Unlike the monoculture of warm-season grasses, the blue grama + western wheatgrass and the buffalograss + western wheatgrass mixture held very uniform color all season, with only a minimum irrigation of 0.50 inches per week needed in the later months. Later irrigation, plus the need for less water amounted to more water savings than KBG or tall fescue.

Compatibility and competition, resistance to winterkill, wear resistance, mowing rate and timing, weed competition, disease and pest tolerance, and fertility studies could be performed on wheatgrass monostands or mixtures before truly knowing if there are desired qualities for various turfgrass situations.

Species and Mixtures Not Recommended for Turfgrass

Due to low quality ratings and higher irrigation needs, some species and mixture did not meet the criteria of an acceptable turfgrass and therefore we did not recommend them for Bozeman, Montana. The grasses did not hold their color and/or had texture or density ratings significantly below the acceptable rating of 5, mostly because repeated mowing affected their appearance. These include: crested wheatgrass, streambank wheatgrass, thickspike wheatgrass, and Canada bluegrass.

Crested wheatgrass, streambank wheatgrass, and thickspike wheatgrass all had low color ratings, as well as less than adequate textures and densities. Although ‘Road Crest’ crested wheatgrass was developed as a drought tolerant grass for maintained roadside use, its color was reduced and, at best, was usually brown-green. The texture and density of crested wheatgrass was low, although densities increased with more moisture. Overall, crested wheatgrass may be drought tolerant, but is not suitable for any kind of turfgrass use.

Streambank and thickspike wheatgrass had a very resilient blade that, when mowed, shredded and produced a white cast over the plots. This white cast detracted from the overall appearance of the grass and caused low color ratings. Textures and densities of the grasses were adequate, but under any kind of mowing these grasses are not recommended. Finally, as with all the wheatgrasses, the higher dry weights meant heavy growth in the early summer in which more frequent mowing would have to occur.

The mixtures and single specie plots containing Canada bluegrass had very low color and texture ratings because of the 'steminess' caused by repeated mowing. When mowed, the internodes of its crowns elongated, creating an inferior turfgrass. In May, Canada bluegrass seemed to be a superior grass. However, as the summer went on, the lush blade growth was removed by mowing and only the 'stem' remained. This caused low texture and color ratings.

The mixtures that contained Canada bluegrass also had lower color and texture because the 'steminess' also was very apparent in those plots. The mixture of Canada bluegrass + western wheatgrass did have higher texture and density scores, but the overall color distracted from its appearance. Currently, Canada bluegrass is being used by some sod producers as a binder species in sod production of drought tolerant turfgrasses. It would be inadvisable to include it in any mixture if mowing heights were to be limited to three inches or lower.

Research and Development

Much turfgrass research and development has gone into KBG and tall fescue. Color, wear resistance, vigor, cold tolerance, and other characteristics have been evaluated and bred into these grasses. This study has shown that some uncommon grasses have some desirable turfgrass qualities comparable to KBG and tall fescue, with proper irrigation and scheduling.

More research has to be performed on selected native and adapted grasses to understand their potential for turfgrass applications. General considerations in overall turfgrass quality such as color, texture, density, spring greenup, seedling vigor and establishment, living ground cover, drought tolerance, frost tolerance, tolerance to winterkill, disease and pest resistance, and wear resistance should be evaluated.

This study was performed on one site and in one environment. However, the species and mixtures that performed well in this study should be more intensively evaluated in the future. Similar studies are being performed in Bridger, Montana, and Logan, Utah, and may produce results in differing soils and environments. The measurements of this experiment, along with the other locations' experimental data, should give a better view into the recommendations for these native and adapted grasses for turfgrass applications.

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APPENDICES

Statistical Analysis for Kentucky Bluegrass, Tall Fescue, Canada Bluegrass, and Crested Wheatgrass

Dry weight

	Kentucky Bluegrass			Tall Fescue			Canada Bluegrass			Crested Wheatgrass		
Effect	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**
Month	4	37.82	<.0001	4	52.64	<.0001	4	63.12	<.0001	4	68.96	<.0001
Subplot	3	0.63	0.6006	3	2.78	0.0493	3	0.10	0.9616	3	0.64	0.5954
Month*Subplot	12	0.91	0.5460	12	1.77	0.0763	12	2.25	0.0210	12	1.09	0.3838

Color

	Kentucky Bluegrass			Tall Fescue			Canada Bluegrass			Crested Wheatgrass		
Effect	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**
Month	4	332.47	<.0001	4	165.09	<.0001	4	31.63	<.0001	4	11.46	<.0001
Subplot	3	51.25	<.0001	3	24.35	0.0001	3	2.83	0.0463	3	6.61	0.0007
Month*Subplot	12	9.62	<.0001	12	5.52	<.0001	12	0.51	0.8972	12	1.54	0.1372

Texture

	Kentucky Bluegrass			Tall Fescue			Canada Bluegrass			Crested Wheatgrass		
Effect	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**
Month	4	33.35	<.0001	4	23.18	<.0001	4	8.75	<.0001	4	3.67	0.0110
Subplot	3	7.87	0.0069	3	12.39	<.0001	3	1.54	0.2150	3	5.40	0.0212
Month*Subplot	12	2.73	0.0067	12	2.45	0.0118	12	0.40	0.9586	12	0.95	0.5044

Density

	Kentucky Bluegrass			Tall Fescue			Canada Bluegrass			Crested Wheatgrass		
Effect	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**
Month	4	32.03	<.0001	4	39.83	<.0001	4	28.03	<.0001	4	6.30	<.0001
Subplot	3	8.77	0.0049	3	21.40	0.0002	3	5.09	0.0034	3	6.22	0.0142
Month*Subplot	12	3.01	0.0032	12	6.51	<.0001	12	1.02	0.4471	12	1.85	0.0667

Statistical Analysis for Sheep Fescue, Streambank Wheatgrass, Thickspike Wheatgrass, and Western Wheatgrass

Dry weight

	Sheep Fescue			**Streambank Wheatgrass**			**Thickspike Wheatgrass**			**Western Wheatgrass**		
Effect	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**
Month	4	36.41	<.0001	4	41.69	<.0001	4	71.53	<.0001	4	58.17	<.0001
Subplot	3	0.89	0.4503	3	1.91	0.1977	3	5.22	0.0232	3	0.28	0.8361
Month*Subplot	12	4.01	0.0002	12	0.60	0.8340	12	3.51	0.0009	12	1.26	0.2667

Color

Effect	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**
Month	4	28.75	<.0001	4	36.05	<.0001	4	17.51	<.0001	4	12.56	<.0001
Subplot	3	10.68	<.0001	3	7.22	0.0003	3	7.60	0.0002	3	8.11	0.0001
Month*Subplot	12	1.89	0.0549	12	1.42	0.1818	12	1.70	0.0915	12	1.66	0.1016

Texture

Effect	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**
Month	4	11.74	<.0001	4	30.43	<.0001	4	18.81	<.0001	4	19.27	<.0001
Subplot	3	16.11	0.0006	3	10.32	0.0028	3	5.70	0.0017	3	11.44	<.0001
Month*Subplot	12	4.11	0.0002	12	3.40	0.0012	12	1.10	0.3757	12	2.63	0.0073

Density

Effect	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**
Month	4	3.56	0.0116	4	6.49	0.0003	4	13.96	<.0001	4	8.18	<.0001
Subplot	3	10.40	<.0001	3	8.72	0.0050	3	5.60	0.0191	3	7.66	0.0002
Month*Subplot	12	2.73	0.0055	12	1.84	0.0686	12	1.64	0.1110	12	1.32	0.2355

Statistical Analysis for Blue Grama, Buffalograss, Canada Bluegrass + Crested Wheatgrass, and Canada Bluegrass + Western Wheatgrass

	Blue grama			**Buffalograss**			**Canada bluegrass + Crested wheatgrass**			**Canada bluegrass + Western Wheatgrass**		
Dry weight												
Effect	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**
Month	4	45.77	<.0001	4	32.57	<.0001	4	65.76	<.0001	4	76.53	<.0001
Subplot	3	1.44	0.2945	3	0.53	0.6718	3	0.15	0.9294	3	1.42	0.2860
Month*Subplot	12	0.83	0.6241	12	2.13	0.0319	12	1.56	0.1305	12	0.89	0.5649
Color												
Effect	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**
Month	4	314.53	<.0001	4	141.82	<.0001	4	31.35	<.0001	4	38.96	<.0001
Subplot	3	6.60	0.0007	3	3.34	0.0699	3	7.40	0.0003	3	9.01	<.0001
Month*Subplot	12	3.43	0.0008	12	1.70	0.0972	12	1.33	0.2303	12	1.78	0.0744
Texture												
Effect	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**
Month	4	147.95	<.0001	4	147.76	<.0001	4	33.09	<.0001	4	4.22	0.0046
Subplot	3	2.53	0.0659	3	2.91	0.0424	3	2.26	0.0916	3	4.41	0.0074
Month*Subplot	12	0.58	0.8487	12	0.70	0.7478	12	0.76	0.6834	12	0.81	0.6405
Density												
Effect	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**
Month	4	11.52	<.0001	4	89.49	<.0001	4	11.86	<.0001	4	1.74	0.1538
Subplot	3	9.10	<.0001	3	6.26	0.0139	3	2.74	0.0517	3	5.91	0.0014
Month*Subplot	12	1.49	0.1538	12	2.71	0.0071	12	0.52	0.8942	12	1.21	0.3012

Statistical Analysis for Western Wheatgrass + Streambank Wheatgrass, Western Wheatgrass + Streambank Wheatgrass + Sheep Fescue, Blue Grama + Western Wheatgrass, and Buffalograss + Blue Grama + Muttongrass

	Western wheatgrass + Streambank wheatgrass			**Western wheatgrass + Streambank wheatgrass + Sheep fescue**			**Blue grama + Western wheatgrass**			**Buffalograss + Blue grama + Muttongrass**		
Dry weight												
Effect	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**
Month	4	45.74	<.0001	4	55.30	<.0001	4	90.09	<.0001	4	41.52	<.0001
Subplot	3	0.99	0.4030	3	0.06	0.9809	3	2.20	0.1579	3	1.10	0.3562
Month*Subplot	12	2.13	0.0289	12	1.75	0.0801	12	1.31	0.2432	12	0.83	0.6213
Color												
Effect	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**
Month	4	30.49	<.0001	4	12.74	<.0001	4	9.61	<.0001	4	184.18	<.0001
Subplot	3	19.93	<.0001	3	8.93	<.0001	3	8.89	<.0001	3	23.37	<.0001
Month*Subplot	12	3.76	0.0003	12	2.04	0.0358	12	1.70	0.0899	12	4.87	<.0001
Texture												
Effect	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**
Month	4	20.81	<.0001	4	38.01	<.0001	4	15.98	<.0001	4	151.38	<.0001
Subplot	3	11.14	0.0022	3	10.12	<.0001	3	6.92	0.0005	3	11.23	<.0001
Month*Subplot	12	2.29	0.0213	12	2.21	0.0230	12	1.25	0.2722	12	2.54	0.0092
Density												
Effect	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**
Month	4	12.25	<.0001	4	40.43	<.0001	4	6.68	0.0002	4	24.14	<.0001
Subplot	3	12.68	<.0001	3	20.52	<.0001	3	5.60	0.0191	3	17.66	<.0001
Month*Subplot	12	2.42	0.0128	12	3.95	0.0002	12	1.67	0.1043	12	3.55	0.0006

Statistical Analysis for Buffalograss + Sheep Fescue and Buffalograss + Western Wheatgrass

Dry weight

	Buffalograss + Sheep fescue			Buffalograss + Western wheatgrass		
Effect	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**
Month	4	11.15	<.0001	4	49.79	<.0001
Subplot	3	0.30	0.8278	3	1.10	0.3578
Month*Subplot	12	2.89	0.0045	12	1.44	0.1752

Color

Effect	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**
Month	4	9.52	<.0001	4	13.31	<.0001
Subplot	3	2.13	0.1671	3	6.82	0.0108
Month*Subplot	12	0.68	0.7587	12	1.53	0.1462

Texture

Effect	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**
Month	4	34.51	<.0001	4	19.16	<.0001
Subplot	3	8.37	0.0057	3	9.12	<.0001
Month*Subplot	12	2.32	0.0197	12	1.89	0.0550

Density

Effect	**DF**	**F Value**	**Pr > F**	**DF**	**F Value**	**Pr > F**
Month	4	33.94	<.0001	4	12.47	<.0001
Subplot	3	2.85	0.0974	3	9.84	<.0001
Month*Subplot	12	0.95	0.5072	12	1.72	0.0861