AN ABSTRACT OF THE THESIS OF

Lisa M. Aguilera for the degree of Master of Science in Rangeland Resources presented on August 25, 2004.

Title: Conditioning of Northern Great Basin Grasses with Livestock Grazing

Abstract Approved:

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Dr. David Ganskopp

Because forage quality of cool season grasses declines to sub-maintenance levels for ruminants late in the growing season in the northern Great Basin, there is a need to elevate protein levels and digestibility of grasses for both wild and domestic ruminants in late summer. Anderson and Scherzinger (1975) proposed using livestock forage conditioning early in the growing season to elevate forage quality of grasses for use later in the year. We tested their forage conditioning hypothesis among 6 grasses with cattle grazing applied at 3 stages in phenology (vegetative, boot, and anthesis) on the Northern Great Basin Experimental Range near Burns, Oregon. Forage quality of regrowth was compared among grazing treatments and with herbage from grasses rested throughout the growing season (ungrazed controls). Indices were: crude protein, in vitro dry matter digestibility, and yield sampled in late July and early September of 1997 and 1998. Grasses included: crested wheatgrass (*Agropyron desertorum* (Fischer ex Link) Schultes), bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. & Smith), bottlebrush squirreltail (*Sitanion hysterix* (Nutt.) J.G.Smith), Idaho fescue (*Festuca idahoensis* Elmer), Thurber needlegrass (*Stipa thurberiana* Piper), and basin wildrye (*Elymus cinereus* Scribn. & Merr). In both years,grasses showed the expected seasonal decline in forage quality (CP and IVDMD) as the season advanced. A positive response to conditioning occurred with crude protein of regrowth ($\bar{x}$ = 7.2 %) in 1997 with a treatment x species interaction ($P < 0.003$) and in 1998 ($\bar{x}$ = 4.6 %) with a significant treatment effect ($P < 0.001$). In vitro dry matter digestibility of regrowth increased for boot and anthesis grazing treatments in 1997 ($\bar{x}$ = 50.4 %) ($P < 0.008$), and for vegetative and boot grazing treatments in July samples of 1998 ($\bar{x}$ = 43.0 %) ($P < 0.007$). Soil moisture content when grasses were grazed was a poor predictor of subsequent regrowth yields. In conclusion, forage-conditioning efforts appeared to be more successful in the drier of the 2 years. Bottlebrush squirreltail and Thurber needlegrass responded most favorably to forage conditioning treatments, while Idaho fescue and bluebunch wheatgrass exhibited the fewest favorable responses.

Conditioning of Northern Great Basin Grasses with Livestock Grazing

by

Lisa M. Aguilera

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CONTRIBUTIONS OF AUTHORS

Dr Dave Ganskopp and Dr Marty Vavra were involved with the design, assisted with data collection and involved with writing of the thesis. Dr Ganskopp assisted in the interpretation of the data. Dr Vavra provided funding for the project.

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GENERAL INTRODUCTION

Cool season grasses in the sagebrush steppe are typically nutrient deficient for ruminants during late summer and fall with nutrient content correlated with plant phenology. Grasses are typically most nutritious during their vegetative stages of phenology and nutrient content diminishes as plants mature (Raleigh 1960, Vavra and Raleigh 1976, Ganskopp and Bohnert 2001). A need to improve forage quality for summer and fall grazing has prompted searches for methods to manipulate or condition forages for use later in the season.

Interest in improving fall and winter forage for wild and domestic ungulates has a long history (Buechner 1952, Frischknecht et al 1953, Bleak and Plummer 1954, Julander 1962, Springfield and Reid 1967). Hyder and Sneva (1963) were first to suggest managers pay attention to the morphology of the grasses during spring grazing to encourage development of desirable forage for late summer or fall grazing. Recently several have studied the utility of forage conditioning with a goal of improving quality and quantity of regrowth (Bryant 1993, Westenskow – Wall et al 1994, Clark et al 1998, Clark et al 2000, Ganskopp et al 2004). Their approach followed Anderson and Scherzinger's (1975) hypothesis that grasses could be grazed while there was sufficient soil moisture for regrowth, and subsequent herbage would cure at an earlier stage of phenology as soil moisture was depleted. The resulting forage would be of higher nutritional value than rested grasses that progressed naturally to maturity.

Ungulates typically seek nutritionally dense forage and ease of grazing. Ganskopp et al (1993) found that steers can selectively harvest diets that are nutritionally superior to the standing crop. Forage containing last year's herbage or old growth is avoided by ungulates. The presence of cured stems lowers the nutritional value of grasses and their palatability (Ganskopp 1992). Wild ungulates also seek high nutritional quality and ease of harvesting, and are often seen foraging among areas previously grazed by livestock (Gordon 1988, and Willms et al 1979, 1980, 1981).

Many techniques have been used to manipulate and improve rangeland forage quality. These include fertilization, burning, chemical curing, and livestock grazing.

Nitrogen fertilization can improve forage quantity, quality, vigor, and plant palatability. In some cases, fertilization may change the abundance of 1 or more species in a stand due to differing competitive responses to nitrate (Miller et al 1986). Responses also depend on species composition and season of nutrient application (Vallentine 1989).

Burning is one of the earliest range improvement practices used by Native Americans to stimulate the growth of grasses, remove cured herbage and woody species, and attract game to hunting areas (Barnes and Baylor 1995). The season, phenology, and vigor of the community determine how plants respond to fire (Daubenmire 1968, Miller et al 1986). The use of fire to remove standing litter can effect the development of grasses like bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. & Smith) for up to 3 years (Miller et al 1986). Burning can improve palatability of grasses by removing old growth, releasing nutrients previously tied-up in plants and soil, and increasing yield (Peek et al 1979, Willms et al 1980, Vallentine 1989).

Top-killing herbicide use during initial growth of grasses can also elevate late season forage quality by curing the standing crop at an earlier stage of phenology. Paraquat has been used experimentally to cure crested wheatgrass (*Agropyron desertorum* (Fischer ex Link) Schultes) in early anthesis, with the resulting herbage being higher in crude protein and other nutrients than naturally cured forage (Sneva 1972, Sneva et al 1973). Haferkamp et al (1987) used mefluidide, a plant growth regulator that can inhibit stem elongation, to improve the quality of crested wheatgrass. An increase in applied mefluidide concentration, reduced the number of reproductive culms, elevated crude protein and digestibility, and decreased neutral detergent fiber (NDF). The improved forage quality was thought to be related to an increase in the relative proportion of leaves.

Growth of grasses in the Pacific Northwest typically stops in early summer as temperatures rise and soil moisture is depleted. In average or better moisture years, grasses typically complete their reproductive efforts before growth is halted by restricted moisture supplies. Conditioning grasses by grazing during early growth stages can potentially stimulate regrowth that may be higher in quality than ungrazed forages. Forage conditioning theory suggests that initial grazing should be done while there is sufficient soil moisture for regrowth. Ganskopp (1998) found regrowth yield of Thurber needlegrass (*Stipa thurberiana* Piper) was positively correlated with soil moisture content on the date of defoliation.

Objectives

The objectives of this study were to evaluate 2 aspects of the forage-conditioning hypothesis and compare responses to those exhibited by ungrazed herbage. These included:

1) Determining the forage quantity and quality responses of regrowth of 6 species of grasses grazed at 3 different stages of phenology, and sampled in late July and mid September.
2) Testing the hypothesis that post grazing regrowth quantity is related to soil moisture content at the time that plants were defoliated.

ABSTRACT

Because forage quality of cool season grasses declines to sub-maintenance levels for ruminants late in the growing season in the northern Great Basin, there is a need to elevate protein levels and digestibility of grasses for both wild and domestic ruminants in late summer. Anderson and Scherzinger (1975) proposed using livestock forage conditioning early in the growing season to elevate forage quality of grasses for use later in the year. We tested their forage conditioning hypothesis among 6 grasses with cattle grazing applied at 3 stages in phenology (vegetative, boot, and anthesis) on the Northern Great Basin Experimental Range near Burns, Oregon. Forage quality of regrowth was compared among grazing treatments and with herbage from grasses rested throughout the growing season (ungrazed controls). Indices were: crude protein, in vitro dry matter digestibility, and yield sampled in late July and early September of 1997 and 1998. Grasses included: crested wheatgrass (*Agropyron desertorum* (Fischer ex Link) Schultes), bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. & Smith), bottlebrush squirreltail (*Sitanion hysterix* (Nutt.) J.G.Smith), Idaho fescue (*Festuca idahoensis* Elmer), Thurber needlegrass (*Stipa thurberiana* Piper), and basin wildrye (*Elymus cinereus* Scribn. & Merr). In both years, grasses showed the expected seasonal decline in forage quality (CP and IVDMD) as the season advanced. A positive response to conditioning occurred with crude protein of regrowth ($\bar{x}$ = 7.2 %) in 1997 with a treatment x species interaction ($P < 0.003$)

and in 1998 ($\bar{x}$ = 4.6 %) with a significant treatment effect ($P<0.001$). In vitro dry matter digestibility of regrowth increased for boot and anthesis grazing treatments in 1997 ($\bar{x}$ = 50.4 %) ($P<0.008$), and for vegetative and boot grazing treatments in July samples of 1998 ($\bar{x}$ = 43.0 %) ($P<0.007$). Soil moisture content when grasses were grazed was a poor predictor of subsequent regrowth yields. In conclusion, forage-conditioning efforts appeared to be more successful in the drier of the 2 years. Bottlebrush squirreltail and Thurber needlegrass responded most favorably to forage conditioning treatments, while Idaho fescue and bluebunch wheatgrass exhibited the fewest favorable responses.

INTRODUCTION

Cool season grasses in the sagebrush steppe are typically nutrient deficient for ruminants during late summer and fall with nutrient content correlated with the plant phenology. Grasses are typically most nutritious during their vegetative stages of phenology and nutrient content diminishes as plants mature (Raleigh 1960, Vavra and Raleigh 1976, Ganskopp and Bohnert 2001). A need to improve forage quality for summer and fall grazing has prompted searches for methods to manipulate or condition forages for use later in the season.

In an early attempt to condition crested wheatgrass, Hyder and Sneva (1963) found that grazing in the spring could stimulate higher quality regrowth for subsequent use in late summer or fall if there was sufficient post grazing soil moisture to sustain herbage production. Anderson and Scherzinger (1975) described a management strategy that stimulated an increase in elk at the Bridge Creek Wildlife Management Area in northeastern Oregon. They theorized that livestock grazing improved forage for wintering wildlife. They believed cattle grazing eliminated standing litter, and if grazing occurred in late spring grasses would regrow and cure at an earlier stage of phenology than ungrazed forages. Grazed forages would subsequently be of higher nutritional value during late summer and fall and potentially more attractive to elk.

Others have made similar observations proposing that forage-conditioning could improve quality of regrowth for grazing later in the season. Pitt (1986) clipped bluebunch wheatgrass at boot, emergence, flowering and seed formation stages of phenology. Clipping at successively later stages improved the nutritional quality of regrowth in the fall. Clipping at the boot stage tended to be similar to unclipped plants (Pitt 1986). Bryant (1993) and Westenskow-Wall, et al (1994) found no response to early spring conditioning but did have enhanced forage quality following fall conditioning.

This study evaluated Anderson and Scherzinger's (1975) hypothesis by testing the utility of cattle grazing for altering the nutritive value of 6 grasses common to the Pacific Northwest and northern Great Basin. Grasses were conditioned at 3 stages of phenology and their subsequent yields, crude protein (CP), and in vitro dry matter digestibility (IVDMD), evaluated in early and late summer.

MATERIALS AND METHODS

Study Area

Twelve study paddocks on the Northern Great Basin Experimental Range near Burns, Oregon were established in spring 1989 by transplanting tussocks from nearby pastures (Cruz and Ganskopp 1998). Individual tussocks were randomly positioned within paddocks (Cruz and Ganskopp 1998). Each paddock contained 75 plants of each forage for sampling. Grasses investigated were crested wheatgrass (*Agropyron desertorum* (Fischer ex Link) Schultes), bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. & Smith), bottlebrush squirreltail (*Sitanion hysterix* (Nutt.) J.G.Smith), Idaho fescue (*Festuca idahoensis* Elmer), Thurber needlegrass (*Stipa thurberiana* Piper), and basin wildrye (*Elymus cinereus* Scribn. & Merr).

Individual plots were delineated with electric fence, and 2 steers were allowed to graze each paddock at the appropriate treatment times. These were at the vegetative, boot, and anthesis stages of phenology as indexed by bluebunch wheatgrass. The goal was for the steers to graze plots to a 2.5 cm stubble. All plots were mowed the previous fall, so only current year's herbage would be sampled the subsequent year.

Soil Moisture Sampling

Soil in the study area was a complex of Milican coarse-loamy, mixed, frigid Orthidic Durixeroll and a loamy fine sand Holtle coarse-loamy, mixed, frigid Aridic Duric Haploxeroll (Ganskopp 1997). Three soil samples were gathered weekly from each treatment beginning on April 15 and ending on

September 15 of 1997 and 1998. Each sample column reached a depth of 30 cm with the top 5 cm discarded to reduce micro-environmental effects. Samples were weighed (wet weight) and dried at 60° C to a constant weight. Samples were reweighed and percent moisture calculated (g wet soil / g dry soil * 100).

Three soil samples were sent to the Soil Physics Laboratory, Department of Crop and Soil Science, Oregon State University, Corvallis, Oregon. Moisture release curves were developed from the gravimetric and volumetric water contents of these samples. The curves were used to convert percent soil moisture content to mega pascal units (Mpa).

Vegetation Sampling

Treatments were randomly assigned to plots within 3 blocks. Again, timing of treatments were indexed to the phenology of bluebunch wheatgrass. Treatments included 1) grazing by cattle at the vegetative stage (30 April 1997 and 5 May 1998), 2) boot stage (14 May 1997 and 18 May 1998), 3) anthesis stage (13 June 1997 and 29 June 1998), and 4) ungrazed controls. Response variables were quantified on 31 July and 15 September. Project design was a randomized complete block with 4 grazing treatments applied to 6 species of grasses among 3 blocks.

Before applying grazing treatments, herbage was sampled from individual tussocks of each species to quantify standing crop and seasonal forage quality. Physical measurements for each tussock included its widest diameter and second widest diameter perpendicular to the first. These measurements were used to derive basal area by solving for the area of an ellipse. Each tussock was clipped to ground level and severed materials placed in a paper bag for drying. Samples were oven dried at 60° C, removed from the oven, immediately weighed. Forage quantity was expressed on a grams per cm^2 basal area basis. Samples were then ground to pass a 1-mm mesh and stored in plastic bags for subsequent lab analyses.

Forage quality was indexed by in vitro dry matter digestibility (IVDMD) (Tilley and Terry 1963) modified for use in an ANKOM Daisy II Incubator[1],[2], incubating for 48 hours and Kjeldahl nitrogen content (AOAC 1984) where crude protein = Kjeldahl nitrogen X 6.25.

Statistical Analysis

Project design was a randomized complete block having 3 blocks and 4 grazing treatments (vegetative, boot, anthesis, and ungrazed controls) applied to 6 grass species. Response variables (regrowth quantity and quality) were quantified on 2 subsequent dates (late July and mid-September).

Seasonal forage quantity and quality were analyzed using a split-plot analysis of variance to test treatment date (main plots, 3 df), species (sub-plots, 5 df), and date x species effects (15 df). Treatment effects were tested with the block x treatment error term (6 df) and species and interaction effects were tested with the residual error term (40 df). Data for individual years were

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[1] ANKOM Technology Corp., Fairport, NY.

[2] Product names are information only and do not convey endorsement of one product over another.

analyzed separately. Mean separations were accomplished with Fischer's protected LSD procedures with statistical significance accepted at $P \leq 0.05$.

Regrowth response variables including standing crop, crude protein content, and IVDMD were analyzed using a split-split-plot analysis of variance. Treatments functioned as main plots (3 df), harvest dates (1 df) as sub–plots, and species of forage (5 df) as sub-sub-plots). Treatment effects were tested with the block x treatment error term (3 df). Harvest date (1 df) and the harvest date x treatment (3df) effects were tested with the block x harvest date x treatment error term (8 df). Species of forage (5 df), treatment x forage (15 df), harvest date x forage (5 df), and the treatment x harvest date x forage (15 df) interaction were tested with the residual error term (80 df). Individual years were analyzed separately. Mean separations were accomplished with Fischer's protected LSD procedures with statistical significance accepted at $P \leq 0.05$. Through out the manuscript, values following "±" symbols are standard errors of the mean.

Regression analyses were used to explore relationships between soil moisture content on the date that grasses were grazed and the subsequent quantity of regrowth at the end of the growing season. Statistical significance was accepted at $P \leq 0.05$.

RESULTS

Precipitation for the 1997 calendar year was 226 mm (80% of average) and 1998 was 310 mm (110 % of average). The average temperature for the 1997 calendar year was 7.8 C with a high of 36.4 C in August and a low of -23.5 C in January. In the 1998 calendar year, the average temperature was 7.9 C, the maximum was 37.9 C in September and the minimum was -24.5 C in December.

Herbage Standing Crop

Seasonal standing crop 1997 and 1998

Due to a great deal of variability among and within species, standing crop of forages at pretreatment samplings did not exhibit significant main (treatment stage, species) or interaction (treatment stage x species) effects ($P>0.05$). Mean standing crop across sampling dates in 1997 was 0.2±0.03 g cm^{-2} basal area, and was 0.3±0.03 g cm^{-2} basal area in 1998.

In 1997 a hailstorm occurred on 11 June. The hailstorm damaged the grasses, and especially affected the reproductive stems. Most likely, the hailstorm also negatively affected standing crop measures.

Regrowth standing crop 1997

In 1997 regrowth standing crop exhibited a significant treatment x species interaction ($P<0.04$) (fig.1) while the 2 regrowth harvest dates had no effect. For regrowth responses from the vegetative treatment, basin wildrye ranked higher than 4 of the 6 species and similar to Thurber needlegrass. Regrowth standing crop was similar among species for boot and anthesis treatments. Standing crop was greater for basin wildrye than the other 5 species for the ungrazed control.

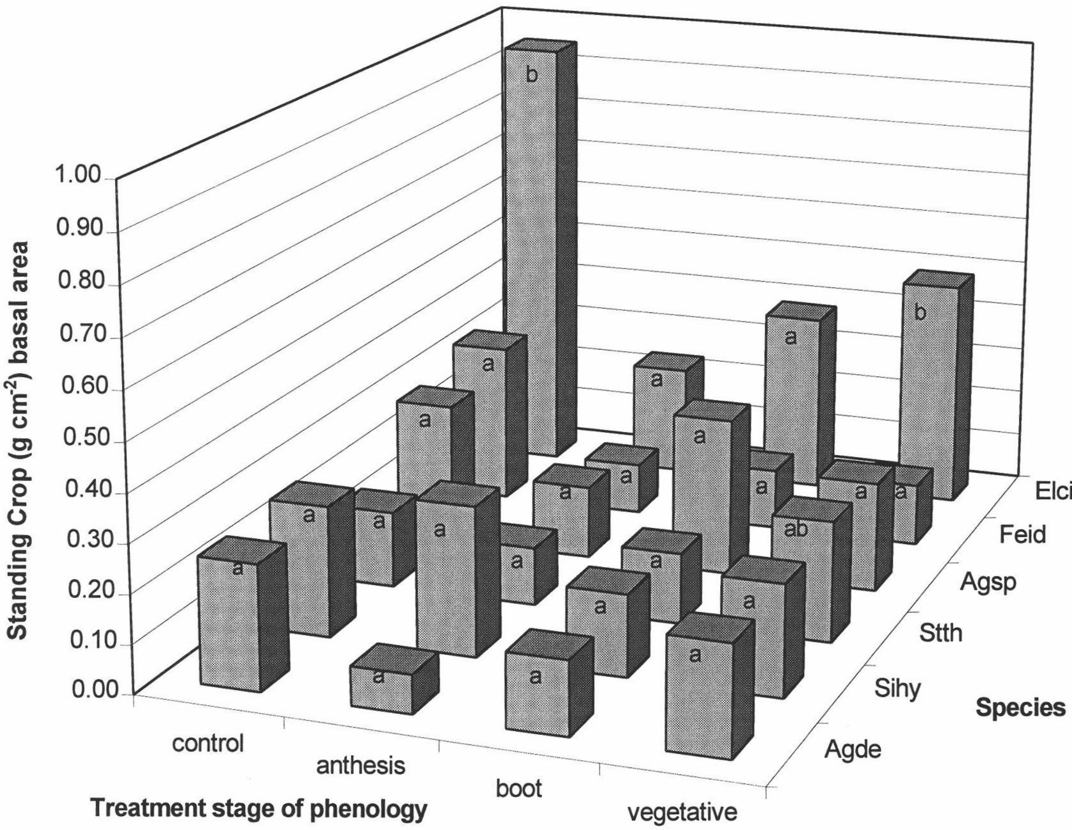

Fig 1. Mean July/September 1997 regrowth standing crop of 6 grasses from grazing treatments at 4 stages of phenology on the Northern Great Basin Experimental Range near Burns, Or. Species means within a treatment (column) sharing a common letter are not significantly different (P>0.05). Agde = crested wheatgrass, Agsp = bluebunch wheatgrass, Sihy = bottlebrush squirreltail, Feid = Idaho fescue, Stth =Thurber needlegrass, Elci = basin wildrye.

Regrowth standing crop 1998

Analyses of regrowth standing crop for 1998 exhibited significant species (P<0.0001) and treatment (P<0.01) main effects (Table 1). For species effects, basin wildrye had the highest standing crop and Thurber needlegrass the lowest standing crop. Both, however, were similar to the remaining 4 grasses. For treatment effects, the ungrazed control standing crop was the highest and greater than regrowth accumulations from vegetative and boot stage treatments. Grasses grazed at anthesis did not generate any regrowth in 1998.

Table 1. Mean (±SE) 1998 July/September regrowth standing crop of 3 grazing treatments and standing crop among 6 grasses on the Northern Great Basin Experimental Range near Burns, Or. Treatment and species means sharing a common letter are not significantly different (P>0.05).

Species	Standing Crop ($g\ cm^{-2}$ basal area)
crested wheatgrass	0.281±0.09ab
bluebunch wheatgrass	0.280±0.07ab
bottlebrush squirreltail	0.263±0.06ab
Idaho fescue	0.211±0.09ab
Thurber needlegrass	0.117±0.03a
basin wildrye	0.434±0.09b
Treatment	**Standing Crop ($g\ cm^{-2}$ basal area)**
vegetative	0.248±0.06a
boot	0.171±0.03a
anthesis	—[1]
control	0.374±0.05b

[1] There was no regrowth from anthesis stage treatment

Crude Protein (%)

Seasonal crude protein patterns in 1997

Crude protein content followed the typical decline in forage quality exhibited by northern Great Basin grasses as plants matured. Not all species performed similarly across time, however, as there was a sampling stage x species interaction (P<0.003) (Fig. 2). Basin wildrye consistently had the highest CP content of all 6 grasses among the 3 grazed treatments. When the grasses were dormant (control), basin wildrye's CP content was similar to Thurber needlegrass, bottlebrush squirreltail, and crested wheatgrass.

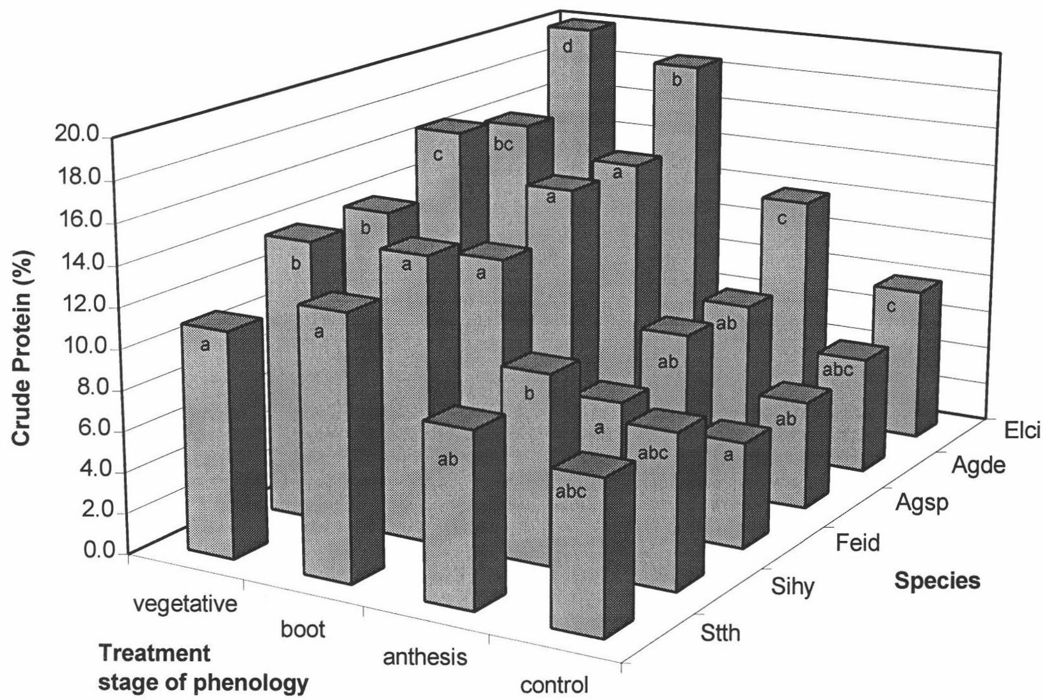

Fig. 2. Mean 1997 seasonal crude protein content of 6 grasses sampled from 4 stages of phenology on the Northern Great Basin Experimental Range near Burns, Or. Species means within a treatment (column) sharing a common letter are not significantly different (P>0.05). Agde = crested wheatgrass, Agsp = bluebunch wheatgrass, Sihy = bottlebrush squirreltail, Feid = Idaho fescue, Stth =Thurber needlegrass, Elci = basin wildrye.

Seasonal crude protein patterns in 1998

We had significant treatment (P<0.001) and species effects (P<0.002) for the CP content of initial growth in 1998 (Table 2). Grasses again exhibited the seasonal depreciation in forage quality typical of the region with sampling at vegetative and boot stages being similar and having the highest CP content. For species effects, basin wildrye again had the highest CP content.

Table 2. Mean (±SE) 1998 seasonal crude protein content of 6 grasses and at 4 stages of development on the Northern Great Basin Experimental Range near Burns, Or. Means sharing a common letter are not significantly different (P>0.05).

Species	CP (%)
crested wheatgrass	8.8±1.3a
bluebunch wheatgrass	9.7±1.5ab
bottlebrush squirreltail	10.0±1.3b
Idaho fescue	9.2±1.2ab
Thurber needlegrass	9.9±1.3ab
basin wildrye	11.2±1.7c
Stage of phenology	CP (%)
vegetative	14.6±0.6c
boot	13.6±0.4c
anthesis	6.8±0.2b
dormant	4.1±0.2a

Regrowth crude protein 1997

The CP content of the regrowth in 1997 had significant treatment x species ($P<0.0003$) (Fig. 3) and treatment x harvest date ($P <0.003$) (Fig. 4) interactions. Bottlebrush squirreltail and Thurber needlegrass typically had the highest CP content in each treatment. In response to grazing at the vegetative stage of phenology, Idaho fescue and basin wildrye were similar to bottlebrush squirreltail and Thurber needlegrass. For herbage not sampled until grasses were dormant (control), basin wildrye was also similar to bottlebrush squirreltail and Thurber needlegrass.

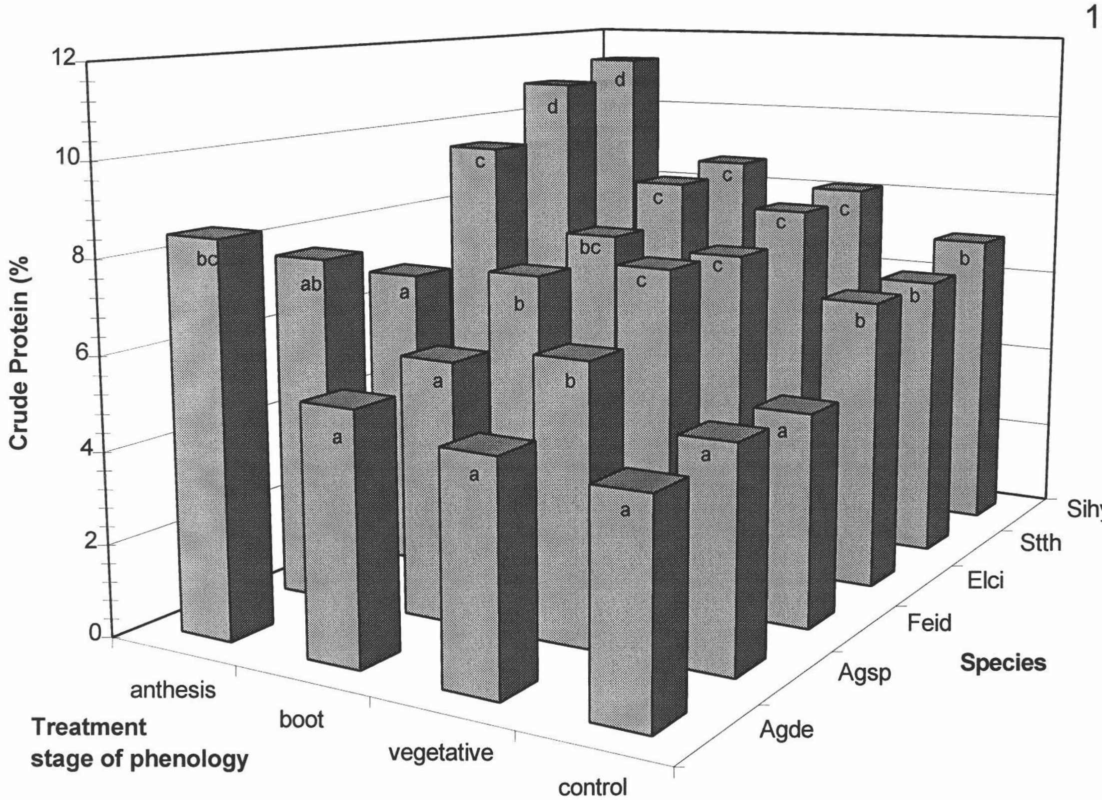

Fig. 3. Mean 1997 crude protein content of regrowth of 6 grasses from 4 grazing treatments derived from pooled late July and mid-September samples on the Northern Great Basin Experimental Range near Burns, Or. Treatment means within a column sharing a common letter are not significantly different (P>0.05). Agde = crested wheatgrass, Agsp = bluebunch wheatgrass, Sihy = bottlebrush squirreltail, Feid = Idaho fescue, Stth =Thurber needlegrass, Elci = basin wildrye.

The treatment x harvest date interaction (Fig. 4) indicated the CP content of regrowth from the grazing treatments responded differently between July and September. CP content from July harvests were higher than material harvested in September. The youngest herbage (anthesis treatment) had the highest CP, while the oldest herbage (ungrazed dormant herbage) was lowest. All grazing treatments differed significantly at the July harvest. By the

September harvest, no separation occurred between regrowth generated by vegetative and boot stage treatments. The premise that the youngest plant material (anthesis grazing) is typically the most nutritious, held true.

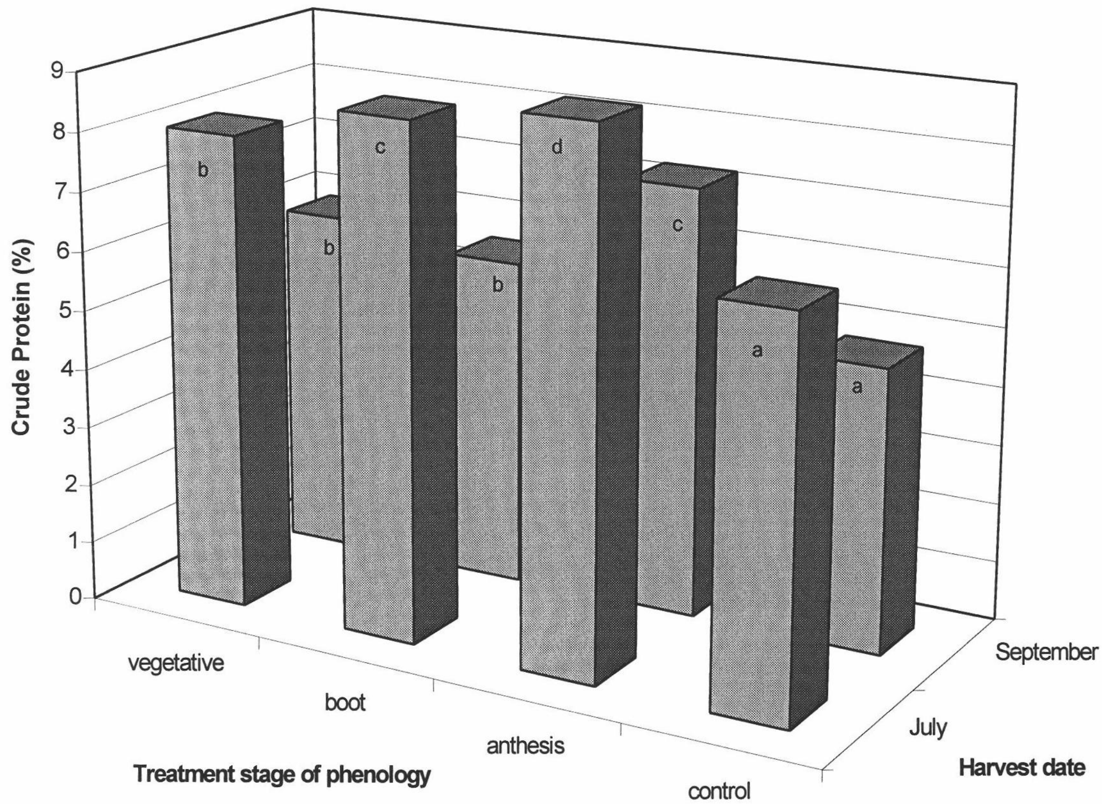

Fig 4. Mean 1997 regrowth crude protein at 2 harvest dates of pooled grass samples from grazing treatments at 4 stages of phenology on Northern Great Basin Experimental Range, near Burns, Or. Treatment means within a harvest date (rows) sharing a common letter are not significantly different (P>0.05).

Regrowth crude protein 1998

In 1998, regrowth responded with significant treatment (P <0.002), harvest date (P<0.0001) and species main effects (P<0.0001) (Table 3).

Among 3 treatments, that generated regrowth, each differed from the others. (Regrowth from the anthesis treatment in 1998 was too minute to measure). Regrowth from boot stage grazing had the highest CP content, second in rank was regrowth from the vegetative treatment and ungrazed herbage was the lowest and ranked third. July and September harvest dates were significantly different from one another with July being 1.4-percentage points higher than September, so we again had a decline between July and September. Among species, 3 categories encompassed the 6 forages. Thurber needlegrass, Idaho fescue, and bottlebrush squirreltail had the highest regrowth CP content, followed by basin wildrye and lastly bluebunch wheatgrass and crested wheatgrass, with the lowest CP content.

Table 3. Mean (±SE) 1998 regrowth crude protein content of 6 grasses, 4 grazing treatments, and 2 harvest dates on the Northern Great Basin Experimental Range near Burns, Or. Means sharing a common letter are not significantly different ($P>0.05$).

Species	CP (%)
crested wheatgrass	3.8±0.2a
bluebunch wheatgrass	4.1±0.3a
bottlebrush squirreltail	5.0±0.3c
Idaho fescue	5.0±0.4c
Thurber needlegrass	5.2±0.3c
basin wildrye	4.5±0.3b
Treatment	**CP (%)**
vegetative	4.6±0.2b
boot	5.5±0.2c
anthesis	—[1]
dormant	3.6±0.1a
Harvest	**CP (%)**
July	5.3+0.2b
September	3.9+0.1a

[1] There was no regrowth from anthesis stage treatment.

Digestibility (% IVDMD)

Seasonal IVDMD 1997

Seasonal digestibility of the grasses exhibited significant sampling stage ($P<0.02$) and species ($P<0.002$) effects (Table 4). Among sampling dates, digestibility from vegetative, boot and anthesis treatments were similar with a significant decline of about 6 percentage points occurring as the grasses matured and cured. Anthesis digestibility was also similar to the ungrazed mature herbage. Among species, basin wildrye had the highest-ranking IVDMD but it was similar to bottlebrush squirreltail, crested wheatgrass and bluebunch wheatgrass. Idaho fescue had the lowest percent IVDMD and was similar to Thurber needlegrass.

Table 4. Mean (±SE) 1997 seasonal IVDMD of 6 grasses and 4 sampling stages on the Northern Great Basin Experimental Range near Burns, Or. Means sharing a common letter are not significantly different ($P>0.05$).

Species	IVDMD (%)
crested wheatgrass	56.7±2.1bc
bluebunch wheatgrass	55.0±2.4bc
bottlebrush squirreltail	57.2±2.0bc
Idaho fescue	48.9±2.4a
Thurber needlegrass	53.4±2.2ab
basin wildrye	59.4±2.2c
Stage of Phenology	**IVDMD (%)**
vegetative	57.8±2.2b
boot	60.1±1.5b
anthesis	54.4±1.5ab
dormant	48.2±1.2a

Seasonal IVDMD 1998

In 1998, we again experienced significant sampling stage ($P<0.0005$) and species ($P<0.001$) effects (Table 5). The highest IVDMD's occurred at vegetative and boot stages of phenology followed with lower digestibilities at anthesis and for mature, ungrazed dormant herbage. For species effects, crested wheatgrass, bottlebrush squirreltail and basin wildrye had the highest IVDMD. Idaho fescue ranked lowest and was similar to Thurber needlegrass.

Table 5. Mean (±SE) 1998 seasonal IVDMD of 6 grasses and 4 sampling stages on the Northern Great Basin Experimental Range near Burns, Or. Means sharing a common letter are not significantly different ($P>0.05$).

Species	IVDMD (%)
crested wheatgrass	64.8±3.3d
bluebunch wheatgrass	61.1±3.9bc
bottlebrush squirreltail	62.8±4.5cd
Idaho fescue	56.0±4.6a
Thurber needlegrass	58.6±4.0ab
basin wildrye	61.6±4.6bcd
Stage of phenology	**IVDMD (%)**
vegetative	69.4±1.6c
boot	74.3±0.8c
anthesis	59.3±1.1b
dormant	40.1±1.5a

Regrowth IVDMD 1997

There were significant treatment ($P<0.008$) and species ($P<0.0001$) effects (Table 6). Regrowth from boot and anthesis treatments had the highest IVDMD. Grazing at the vegetative stage of phenology did not improve digestibility, as herbage was similar to dormant, ungrazed forage. For species effects, 3 separations occurred among the grasses. Basin wildrye, crested wheatgrass, Thurber needlegrass and bottlebrush squirreltail had the highest IVDMD. Bluebunch wheatgrass was ranked second and Idaho fescue the lowest IVDMD.

Table 6. Mean (±SE) regrowth IVDMD of 6 grasses and 4 grazing treatments on the Northern Great Basin Experimental Range near Burns, Or in 1997. Means sharing a common letter are not significantly different (P>0.05).

Species	IVDMD (%)
crested wheatgrass	53.3±1.1c
bluebunch wheatgrass	47.4±1.1b
bottlebrush squirreltail	51.6±1.4c
Idaho fescue	43.4±1.0a
Thurber needlegrass	53.2±1.3c
basin wildrye	53.6±1.6c
Treatment	**IVDMD (%)**
vegetative	47.2±0.9a
boot	52.1±0.9b
anthesis	55.2±1.4b
dormant	47.2±0.9a

Regrowth IVDMD 1998

There was a treatment x harvest date ($P<0.007$) (Fig 5) interaction and a significant species ($P<0.003$) effect for regrowth generated in 1998 (Table 7). For the treatment x harvest date interaction, July regrowth from vegetative and boot stage treatments had the highest mean digestibilities and were significantly greater than the herbage from ungrazed controls. In September, neither of the 2 grazed treatments enhanced digestibilities when compared to ungrazed dormant herbage. Again, no regrowth was generated by the anthesis treatment in 1998. For species effects, crested wheatgrass regrowth had the highest digestibility. Idaho fescue was the lowest for both 1997 and 1998.

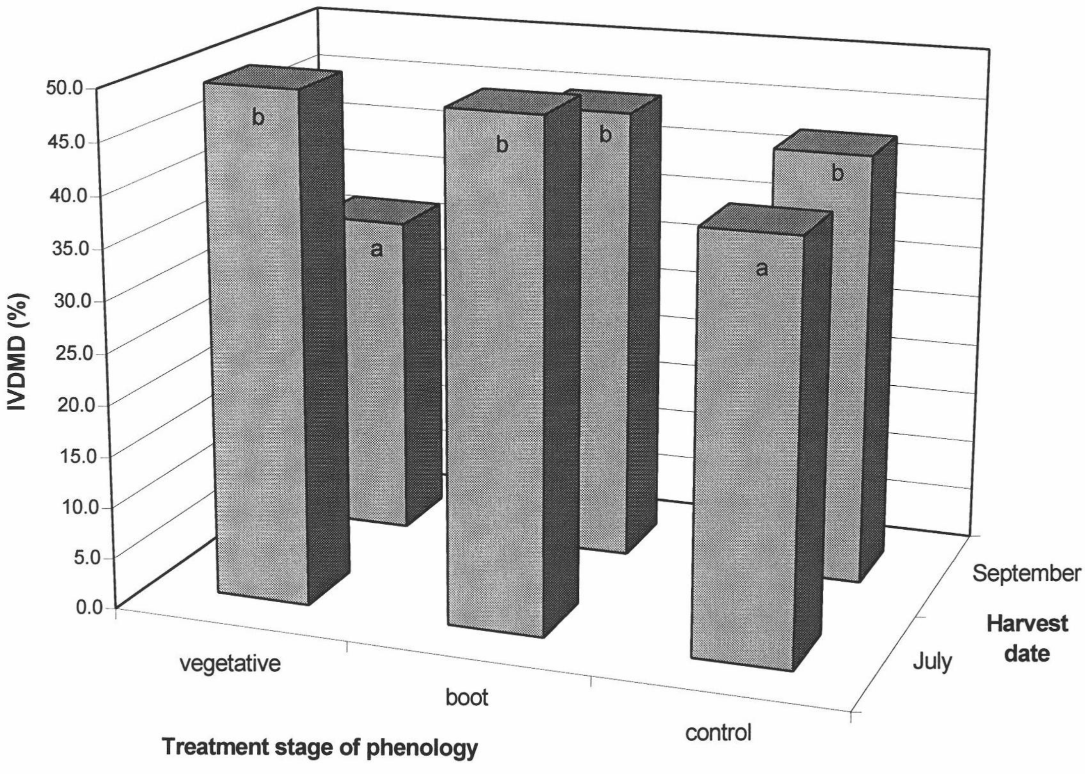

Fig. 5. Mean 1998 regrowth in vitro dry matter digestibility (IVDMD) at 2 harvest dates from pooled grass samples from grazing treatments at 3 stages of phenology on the Northern Great Basin Experimental Range near Burns, Or. Treatment means within a harvest date (rows) sharing a common letter are not significantly different (P>0.05). There was no regrowth from the anthesis treatment.

Table 7. Mean (±SE) 1998 IVDMD regrowth from 6 grasses on the Northern Great Basin Experimental Range near Burns, Or. Species means sharing a common letter are not significantly different (P>0.05).

Species	IVDMD (%)
crested wheatgrass	46.3±1.5c
bluebunch wheatgrass	42.4±1.8ab
bottlebrush squirreltail	42.9±1.8b
Idaho fescue	40.3±2.1a
Thurber needlegrass	43.3±1.9b
basin wildrye	42.5±2.0ab

Soil Moisture Regrowth Standing Crop Relationships

There were no significant relationships between standing crop of regrowth and soil moisture levels when grasses were grazed for any of the forages sampled. Soil moisture is required for regrowth to occur, but our results suggest that other factors need to be taken into account when predicting regrowth standing crop. Most likely regrowth is affected by a complex of factors like temperature, plant phenology, and resource allocation differences among species (Blaisdell 1958, Sneva 1977, Sneva 1982, Miller et al 1990). The highest r^2 obtained was a meager 0.137 for crested wheatgrass.

DISCUSSION

Cool-season perennial grasses in the sagebrush steppe are typically low in nutrient content during late summer and fall (Raleigh 1960, Skovlin 1967, Vavra and Raleigh 1976, Van Soest 1994). Cool-season grasses begin growing in early spring, and continue to grow until they enter the reproductive stage of phenology about late June. Once they have completed their reproductive efforts the grasses become dormant, and they may or may not respond to mid-summer moisture by producing regrowth (Laude 1953, Ganskopp and Bohnert 2001).

Grasses in the vegetative stage of phenology contain high levels of CP and are highly digestible. Grass leaves are higher in crude protein, lower in fiber and higher in digestibility than stems. As the grasses mature, reproductive stems elongate, may increase in number, and their presence elevates plant lignin content (Van Soest 1994). By August, grasses become nutritionally deficient for livestock and wild ungulates. Our samples taken at 4 different stages of development (vegetative, boot, anthesis, and maturity) and July 31 and September 15, showed the expected decline in quality as the season advanced (Fig. 2, Table 2). CP in both years was highest at the end of April and continually declined to mid-September. In 1997, Thurber needlegrass exhibited a low CP content at the end of April, increased in CP by mid-May and declined in CP thereafter. A similar pattern occurred in 1998 with bluebunch wheatgrass. Digestibility values appeared highest at the end of April through mid-May and declined throughout the rest of the season

(Table 4, 5). No species differences were seen in the biomass of initial standing crop across the grazing season in both years.

The forage-conditioning hypothesis proposes that grazing or cutting grass with sufficient soil moisture for regrowth will improve forage quality later in the season (Hyder and Sneva 1963, Hedrick et al. 1969). Species responses varied in our conditioning efforts. Bottlebrush squirreltail seemed to be a "model" grass for conditioning. Its CP content and digestibility consistently improved with conditioning. Conditioned basin wildrye also had high CP content and digestibility. Also regrowth standing crop of basin wildrye in response to vegetative stage treatment was higher than the other grasses probably because of the plant's large stature. Thurber needlegrass had improved CP content and digestibility with conditioning. Forage characteristics of Idaho fescue were variable, but it exhibited consistently low digestibilities. Crested wheatgrass responded to conditioning with both low digestibility and low CP content compared to the other 5 grasses. Bluebunch wheatgrass had variable forage quality characteristics and did not appear to strongly respond to forage conditioning efforts.

A beef cow on range in late summer / early fall, is typically lactating and gestating. Likewise, a 2 or 3 year old heifer also needs nutrients for growth. On an all forage diet, cattle eating low quality forages (<6 to 8% CP) tend to have depressed feed intake (National Research Council, 1996), depressed weight gains in calves and yearlings, and mature cows may experience weight loss (Vavra and Raleigh 1976). Crude protein requirements for a lactating and gestating 450 kg. cow in July is 8.41%, August 7.97%, and September 7.51% assuming calving occurs in April (National Research Council, 1996). Our ungrazed herbage CP levels at the end of July in 1997 averaged 6.6%. Basin wildrye contained 7.9% CP, which would have been adequate for cows in August. By September the average CP level was 4.8%, and none of the ungrazed grasses provided adequate CP. For regrowth in 1997, the end of July CP content of the grasses grazed at the vegetative stage was 8.0%, boot stage 8.7%, and anthesis 10.8%. By September however, none of the grasses contained adequate CP for cattle. In 1998, the ungrazed herbage CP level was 4.1% at the end of July. Mid-September CP was 3.1%. In 1998, regrowth from grazed treatments in July (5.3%) or September (3.9%) had deficient CP levels. Cattle have been known to selectively graze the more succulent, higher quality portions of a plant as well as locations on the landscape that provide more appetizing feed, like depressions and swales (Harris 1968, Karn and Ries 2002). By doing so, cattle acquire forage that is higher in quality than whole plant or stand samples. With the low CP content found in ungrazed herbage and the regrowth of grasses in 1998, it may be difficult for a cow to compensate with selective grazing for such severe deficiencies. One should monitor the CP content of the grasses on the range and supplement with other protein sources or move cattle to 'greener pastures'.

Range forages will not provide adequate nutritional quality for wintering wild ungulates and it is expected they will lose weight during this time Wambolt et al 1997). It has been suggested (White 1983, Albon and Langvatn 1992) that even small improvements in forage quality may be important to these animals for weight gain and effects on fecundity and winter survival. The cumulative effects of grazing even marginally improved regrowth and selective grazing over the 4 to 5 month wintering period will help by allowing the animals to mobilize less of their body stores. In this way, regrowth is used as a supplement to lower quality current-year forage (Frisina 1992).

One obvious draw back to forage conditioning is a decrease in yield. It has been shown in previous studies that total growing season biomass is typically reduced when grasses are conditioned, especially in the boot stage of phenology (Blaisdell and Pechanec 1949, Hyder and Sneva 1963, Krall et al 1971, Ganskopp 1998, Ganskopp et al 2004). In this study, none of the treatments in either 1997 or 1998 improved the standing crop over the ungrazed control. In the 1997 portion of this study, there was a grazing treatment x species interaction for regrowth standing crop. All grasses were similar in response to grazing treatments except for basin wildrye and Thurber needlegrass, which had the highest regrowth standing crop in response to the vegetative stage treatment. Basin wildrye also had the highest standing crop among the ungrazed controls. In 1998, a significant difference was found between the regrowth standing crop of treatments among vegetative, boot, and the ungrazed control treatments. Regrowth samples were too minute to measure after the anthesis treatment. One might caution that grazing at the end of June will not allow for regrowth and one should condition forage when there is a less negative impact on the grasses.

Some grasses are more able than others to take advantage of available soil moisture for regrowth. Sneva (1977) noted crested wheatgrass is very slow to respond to summer moisture whereas native bluegrasses respond to late summer rains (Skovlin 1967, Sneva 1977, 1982). Usually grasses that can take advantage of these rains have dense, shallow roots (Skovlin 1962). Bottlebrush squirreltail is another grass that often responds to mid-summer moisture (Ganskopp and Bohnert 2001).

Those promoting forage-conditioning practices infer that grasses should initially be defoliated while there is still sufficient soil moisture to support regrowth (Anderson and Scherzinger 1975, Pitt 1986). One might intuitively hypothesize that soil moisture content at the time that grasses were grazed would be a good predictor of regrowth yield (Currie and Peterson 1966, Ganskopp 1998). My findings, however, do not support that hypothesis. Regressions relating soil moisture content when grasses were grazed to regrowth yields at the end of July or mid-September did not yield any statistically significant models among the 6 grasses sampled. Soil moisture is required for regrowth, but other factors need to be taken into account when predicting regrowth standing crop such as stage of phenology and resource allocation patterns of grasses, soil and air temperature, photo-period, and probably other unrealized variables (Miller et al 1990, Sneva 1977, Sneva 1982).

A management plan can use livestock forage conditioning as a tool to change the structure and quality of plant species on a site and potentially make the site more attractive to stock or wildlife. Livestock forage conditioning can remove previous year's old growth that makes the forage less palatable (Ganskopp et al 1992). This allows ease of access to the more nutrient dense regrowth forage. As livestock graze and move over the landscape, patches of improved forage quality will be produced (Vavra and Sheehy 1996). The areas where the soil is deeper and subsequently more soil moisture is available may support regrowth of the forages. Areas with shallower soils and lower soil moisture may not generate regrowth. Regrowth forage from spring defoliation can help deter shrub or forb use by ungulates due to the improved palatability of the grasses (Ganskopp et al 1999). Forage conditioning can also be applied to rotational grazing practices using the regrowth forage as a supplement to current year's growth (Frisina 1992).

Forage conditioning can be a useful tool to improve the quality of herbage for grazing later in the season. There are risks to forage conditioning, however. First one may be unable to stimulate regrowth with forage conditioning. Second, if regrowth is produced, the quality may not be much better than that of ungrazed grasses. Bottlebrush squirreltail and Thurber needlegrass appear to be the most responsive in quality, of the grasses sampled, to forage conditioning. Basin wildrye had good responses in both quality and quantity to forage conditioning. Idaho fescue, and especially bluebunch wheatgrass, had such variable responses to conditioning that success with these species is unlikely. Soil moisture on the day of conditioning was a poor predictor of regrowth standing crop.

LITERATURE CITED

Albon, S.D. and R. Langvatn. 1992. Plant phenology and the benefits of migration in a temperate ungulate. Oikos 65:502-513.

Anderson, E.W., and R.J. Scherzinger. 1975. Improving quality of winter forage for elk by cattle grazing. J. Range Manage. 28:120-125.

AOAC. 1984. Official methods of analysis (14th Ed.) Assoc. of Official Analytical Chem. Arlington, Virg.

Blaisdell, J.P. 1958. Seasonal development and yield of native plants on the upper Snake River plains and their relation to certain climatic factors. US Dept Agric Tech Bull No. 1190.

Blaisdell, J.P., and J.F. Pechanec. 1949. Effects of herbage removal at various dates on vigor of bluebunch wheatgrass and arrowleaf balsamroot. Ecology 30:298-305.

Bryant, L.D. 1993. Quality of bluebunch wheatgrass (*Agropyron spicatum*) as a winter range forage for Rocky Mountain elk (*Cervus elaphus nelsoni)* in the Blue Mountains of Oregon. PhD. Thesis. Oregon State Univ., Corvallis.

Cruz, R, and D. Ganskopp. 1998. Seasonal preferences of steers for prominent northern Great Basin grasses. J. Range Manage. 51:557-565.

Currie, P.O. and G. Peterson. 1966. Using growing –season precipitation to predict crested wheatgrass yields. J. Range Manage. 19:284-288.

Frisina, M.R. 1992. Elk habitat use within a rest-rotation grazing system. Rangelands 14:93-96.

Ganskopp, D. 1997. Preferences and behavior of cattle grazing 8 varieties of grasses. J. Range Manage. 50:578-586.

Ganskopp, D. 1998. Thurbers needlegrass: Seasonal defoliation effects on forage quantity and quality. J. Range Manage. 51:276-281.

Ganskopp, D., and D. Bohnert. 2001. Nutritional dynamics of 7 northern Great Basin Grasses. J. Range Manage. 54:640-647.

Ganskopp, D., R. Angell, and J. Rose. 1993. Effect of low densities of senescent stems in crested wheat grass on plant selection and utilization by beef cattle. Appl. Anim. Behav. Sci. 38:227-233.

Ganskopp, D., T. Svejcar, F. Taylor, J. Farstvedt, and K. Painter. 1999. Seasonal cattle management in 3- to 5- year old bitterbrush stands. J. Range Manage. 52:166-173.

Ganskopp, D., T. Svejcar, M. Vavra. 2004. Livestock forage conditioning: Bluebunch wheatgrass, Idaho fescue, and bottlebrush squirreltail. J. Range Manage. 57:384-392.

Harris, L.E., N.C. Frischknecht, and E.M. Sudweeks. 1968. Seasonal grazing of crested wheatgrass by cattle. J. Range Manage. 21:221-225.

Hedrick, D.W., and L.A. Stoddart. 1940. Effect of grazing upon bunch wheatgrass. J. Amer. Soc. Agron. 32:278-289.

Hyder, D.N., and Sneva, F.A. 1963. Morphological and physiological factors affecting the grazing management of crested wheatgrass. Crop Sci. 3:267-271.

Karn, J.R., R.E. Ries. 2002. Free-choice grazing of native range and cool-season grasses. J. Range Manage. 55:469-473.

Krall, J.L., JR.Stroh, C.S. Cooper, and S.R. Chapman. 1971. Effect of time and extent of harvesting basin wildrye. J. Range Manage. 24:414-418.

Laude, H.M. 1953. The nature of summer dormancy in perennial grasses. Bot. Gaz. 114:284-292.

Miller, R.F., M.R. Haferkamp, R.F. Angell. 1990. Clipping date effects on soil water and regrowth in crested wheatgrass. J. Range Manage. 43:253-257.

NRC. 1996. Nutrient Requirements of Beef Cattle. Nat. Res. Counc., Washington, D.C.

Pitt, M.D. 1986. Assessment of sprin defoliation to improve fall forage quality of bluebunch wheatgrass (*Agropyron spicatum*). J. Range Manage. 39:175-180.

Raleigh, R.J. 1960. Symposium on pasture methods for maximum production in beef cattle: Manipulation of both livestock and forage management to give optimum production. J. Anim. Sci. 30:108-114.

Skovlin, J.M. 1962. Cow and calf weight trends on mountain summer range. US Dept of Agr, Forest Serv. Research Note, PNW-220.

Skovlin, J.M. 1967. Fluctuations in forage quality on summer range in the Blue Mountains. USDA For Serv Res Paper PNW-44.

Sneva, F.A. 1977. Correlations of precipitation and temperature with spring, regrowth, and mature crested wheatgrass yields. J. Range Manage. 30:270-275.

Sneva, F.A. 1982. Relation of precipitation and temperature with yield of herbaceous plants in eastern Oregon. Int. J. Biometeor. 26:263-276.

Tilley, J.M.A., and R.A.Terry. 1963. A two-stage technique for the in vitro digestion of forage crops. J. Brit. Grassl. Soc. 18:104-111.

Van Soest, P.J. 1994. Nutritional concepts. In: Nutritional Ecology of the Ruminant. Ithaca. Cornell Univ. Press.

Vavra, M. and R.J. Raleigh. 1976. Coordinating beef cattle management with the range forage resource. J. Range Manage. 29:449-452.

Vavra, M., and D.P. Sheehy. 1996. Improving elk habitat characteristics with livestock grazing. Rangelands 18:182-185.

Wambolt, C.L., M.R. Frisina, K.S. Douglass, and H.W. Sherwood. 1997. Grazing effects on nutritional quality of bluebunch wheatgrass for elk. J. Range Manage. 50:503-506.

Westenskow – Wall, K. J., W. C. Krueger, L. D. Bryant, and D. R. Thomas. 1994. Nutrient quality of bluebunch wheatgrass regrowth on elk winter range in relation to defoliation. J. Range Manage. 47:240-244.

Willms, W., A. McLean, R. Tucker, and R. Ritcey. 1979. Interactions between Mule Deer and Cattle on Big Sagebrush Range in British Columbia. J. Range Manage. 32:299-304.

Willms, W., A.W. Bailey and A. McLean. 1980. Effect of burning or clipping *Agropyron spicatum* in the autumn on the spring foraging behavior of mule deer and cattle. J. Appl. Ecol. 17:69-84.

Willms, W., A.W. Bailey, A. McLean and R. Tucker. 1981. The effects of fall defoliation on the utilization of bluebunch wheatgrass and its influence on the distribution of deer in the spring. J. Range Manage. 34:16-18.

White, R.G. 1983. Foraging patterns and their multiplier effects on productivity of northern ungulates. Oikos 40:377-384.

GENERAL CONCLUSION

Cool season grasses in the sagebrush steppe are typically low in nutrient content during late summer and fall (Raleigh 1960, Skovlin 1967, Vavra and Raleigh 1976, Van Soest 1994). Cool-season perennial grasses begin growing in early spring, and continue to grow until they enter the reproductive stage of phenology about late June. Once they have completed their life cycle grasses become dormant, and they may or may not respond to mid-summer moisture by producing regrowth (Laude 1953, Ganskopp and Bohnert 2001).

In late summer / early fall, a beef cow on range is lactating and gestating. If she is a 2 or 3 year old heifer she also needs nutrients for growth. On an all forage diet, cattle eating low quality forages (<6 to 8% CP) tend to have depressed feed intake (National Research Council, 1996), depressed weight gains in calves and yearlings, and mature cows may experience weight loss (Vavra and Raleigh 1976). With the low CP content found in ungrazed herbage and regrowth of grasses in 1998, it would be difficult for a cow to compensate with selective grazing for such deficiencies. One should monitor the CP content of the grasses their herd is grazing and supplement with other protein sources as needed or move the cattle to 'greener pastures'.

The forage conditioning hypotheses proposes grazing or cutting grass when there is sufficient soil moisture for regrowth to potentially improve forage quality later in the season for ungulate grazing (Hedrick and Stoddart 1940, Hyder and Sneva 1963). One obvious draw back to forage conditioning is a decrease in yield. It has been seen in previous studies that total growing season biomass is reduced when grasses are conditioned, especially in the boot stage (Blaisdell and Pechanec 1949, Hyder and Sneva 1963, Krall et al 1971, Ganskopp 1998).

A management plan can use livestock forage conditioning as a tool to change the structure and quality of plant species on a site and potentially make the site more attractive to other wildlife. Forage conditioning can also be applied to rotational grazing practices using the regrowth forage as a supplement to current year's growth (Frisina 1992).

Forage conditioning can be a useful tool to improve the quality of forage for grazing later in the season. There is a risk that there will not be sufficient soil moisture to stimulate regrowth or that by the time one decides to utilize the regrowth, the quality would not be much better than the ungrazed grasses. We found bottlebrush squirreltail and Thurber needlegrass appeared to be the most responsive to forage conditioning. Idaho fescue and bluebunch wheatgrass had such variable responses to conditioning that one should not expect them to often be successfully conditioned. Soil moisture on the day of conditioning was found to be a poor predictor of regrowth yields.

BIBLIOGRAPHY

Albon, S.D. and R. Langvatn. 1992. Plant phenology and the benefits of migration in a temperate ungulate. Oikos 65:502-513.

Anderson, E.W., and R.J. Scherzinger. 1975. Improving quality of winter forage for elk by cattle grazing. J. Range Manage. 28:120-125.

AOAC. 1984. Official methods of analysis (14^{th} Ed.) Assoc. of Official Analytical Chem. Arlington, Virg.

Barnes, R.F., and J.E. Baylor. 1995. Forages in a changing world. p.3-13. *In*: Barnes, Robert F., Darrell A. Miller, C. Jerry Nelson (eds.) Forages Vol. 1, An introductin to grassland agriculture. Iowa State Univ. Press, Ames, Iowa.

Blaisdell, J.P., and J.F. Pechanec. 1949. Effects of herbage removal at various dates on vigor of bluebunch wheatgrass and arrowleaf balsamroot. Ecology 30:298-305.

Bleak, A.T., and A.P. Plummer. 1954. Grazing crested wheatgrass by sheep. J. Range Manage. 7:63-68.

Buechner, H.K. 1952. Winter-range utilization by elk and mule deer in southeastern Washington. J. Range Manage. 5:76-80.

Bryant, L.D. 1993. Quality of bluebunch wheatgrass (*Agropyron spicatum*) as a winter range forage for Rocky Mountain elk (*Cervus elaphus nelsoni)* in the Blue Mountains of Oregon. PhD. Thesis. Oregon State Univ., Corvallis.

Clark, P.E., W.C. Krueger, Larry D. Bryant , and David R. Thomas. 1998. Spring defoliation effects on bluebunch wheatgrass: I. Winter forage quality. J. Range Manage. 51:519-525.

Clark, P.E., W.C. Krueger, L.D. Bryant , and D.R. Thomas. 2000. Livestock grazing effects on forage quality of elk winter range. J. Range Manage. 53:97-105.

Cruz, R, and D. Ganskopp. 1998. Seasonal preferences of steers for prominent northern Great Basin grasses. J. Range Manage. 51:557-565.

Currie, P.O. and G. Peterson. 1966. Using growing –season precipitation to predict crested wheatgrass yields. J. Range Manage. 19:284-288.

Daubenmire, R. 1968. Ecology of fire in Grasslands. Adv. Ecol. Res. 5:209-266.

Frischknecht, N.C., L.E. Harris, and H.K. Woodward. 1953. Cattle gains and vegetal changes as influenced by grazing treatments on crested wheatgrass. J. Range Manage. 6:151-158.

Frisina, M.R. 1992. Elk habitat use within a rest-rotation grazing system. Rangelands 14:93-96.

Ganskopp, D. 1997. Preferences and behavior of cattle grazing 8 varieties of grasses. J. Range Manage. 50:578-586.

Ganskopp, D. 1998. Thurbers needlegrass: Seasonal defoliation effects on forage quantity and quality. J. Range Manage. 51:276-281.

Ganskopp, D., and D. Bohnert. 2001. Nutritional dynamics of 7 northern Great Basin Grasses. J. Range Manage. 54:640-647.

Ganskopp, D., R. Angell, and J. Rose. 1992. Response of cattle to cured reproductive stems in a caespitose grass. J. Range Manage. 45:401-404.

Ganskopp, D., R. Angell, and J. Rose. 1993. Effect of low densities of senescent stems in crested wheat grass on plant selection and utilization by beef cattle. Appl. Anim. Behav. Sci. 38:227-233.

Ganskopp, D., T. Svejcar, M. Vavra. 2004. Livestock forage conditioning: Bluebunch wheatgrass, Idaho fescue, and bottlebrush squirreltail. J. Range Manage. 57:384-392.

Gordon, I.J. 1988. Facilitation of red deer grazing by cattle and its impact on red deer performance. J. Appl. Ecol. 25:1-9.

Haferkamp, M.R., R.F. Miller, and F.A. Sneva. 1987. Mefluidide effects on forage quality of crested wheatgrass. Agron. J. 79:637-641.

Harris, L.E., N.C. Frischknecht, and E.M. Sudweeks. 1968. Seasonal grazing of crested wheatgrass by cattle. J. Range Manage. 21:221-225.

Hedrick, D.W., and L.A. Stoddart. 1940. Effect of grazing upon bunch wheatgrass. J. Amer. Soc. Agron. 32:278-289.

Hyder, D.N., and Sneva, F.A. 1963. Morphological and physiological factors affecting the grazing management of crested wheatgrass. Crop Sci. 3:267-271.

Julander, O. 1962. Range management in relation to mule deer habitat and herd productivity in Utah. J. Range Manage. 15:278-281.

Karn, J.R., R.E. Ries. 2002. Free-choice grazing of native range and cool-season grasses. J. Range Manage. 55:469-473.

Krall, J.L., JR.Stroh, C.S. Cooper, and S.R. Chapman. 1971. Effect of time and extent of harvesting basin wildrye. J. Range Manage. 24:414-418.

Laude, H.M. 1953. The nature of summer dormancy in perennial grasses. Bot. Gaz. 114:284-292.

Miller, R.F., J.M. Seufert, and M.R. Haferkamp. 1986. The ecology and management of bluebunch wheatgrass (*Agropyron spicatum*): A Review. Agric. Exper. Sta. Bulletin 669. 39 p.

Miller, R.F., M.R. Haferkamp, R.F. Angell. 1990. Clipping date effects on soil water and regrowth in crested wheatgrass. J. Range Manage. 43:253-257.

NRC. 1996. Nutrient Requirements of Beef Cattle. Nat. Res. Counc., Washington, D.C.

Peek, M.J., and R.A. Riggs, and J.R. Lauer. 1979. Evaluation of fall burning on bighorn sheep winter range. J. Range Manage. 32:430-432.

Pitt, M.D. 1986. Assessment of sprin defoliation to improve fall forage quality of bluebunch wheatgrass (*Agropyron spicatum*). J. Range Manage. 39:175-180.

Raleigh, R.J. 1960. Symposium on pasture methods for maximum production in beef cattle: Manipulation of both livestock and forage management to give optimum production. J. Anim. Sci. 30:108-114.

Skovlin, J.M. 1962. Cow and calf weight trends on mountain summer range. US Dept of Agr, Forest Serv. Research Note, PNW-220.

Skovlin, J.M. 1967. Fluctuations in forage quality on summer range in the Blue Mountains. USDA For Serv Res Paper PNW-44.

Sneva, F.A. 1972. Nitrogen and paraquat saves range forage for fall grazing. J. Range Manage. 26:294-295.

Sneva, F.A. 1977. Correlations of precipitation and temperature with spring, regrowth, and mature crested wheatgrass yields. J. Range Manage. 30:270-275.

Sneva, F.A. 1982. Relation of precipitation and temperature with yield of herbaceous plants in eastern Oregon. Int. J. Biometeor. 26:263-276.

Sneva, F.A., R.J. Raleigh, and H.A. Turner. 1973. Paraquat-cured herbage for late season grazing. J. Range Manage. 36:107-113.

Springfield, H.W., and E.H. Reid. 1967. Crested wheatgrass for spring grazing in northern New Mexico. J. Range Manage. 20:406-408.

Tilley, J.M.A., and R.A.Terry. 1963. A two-stage technique for the in vitro digestion of forage crops. J. Brit. Grassl. Soc. 18:104-111.

Vallentine, J.F. 1989. Range fertilization. *In:* Range Development and Improvements. San Diego: Acacemic Press, Inc.

Van Soest, P.J. 1994. Nutritional concepts. In: Nutritional Ecology of the Ruminant. Ithaca. Cornell Univ. Press.

Vavra, M. and R.J. Raleigh. 1976. Coordinating beef cattle management with the range forage resource. J. Range Manage. 29:449-452.

Wambolt, C.L., M.R. Frisina, K.S. Douglass, and H.W. Sherwood. 1997. Grazing effects on nutritional quality of bluebunch wheatgrass for elk. J. Range Manage. 50:503-506.

Westenskow – Wall, K. J., W. C. Krueger, L. D. Bryant, and D. R. Thomas. 1994. Nutrient quality of bluebunch wheatgrass regrowth on elk winter range in relation to defoliation. J. Range Manage. 47:240-244.

Willms, W., A. McLean, R. Tucker, and R. Ritcey. 1979. Interactions between Mule Deer and Cattle on Big Sagebrush Range in British Columbia. J. Range Manage. 32:299-304.

Willms, W., A.W. Bailey and A. McLean. 1980. Effect of burning or clipping *Agropyron spicatum* in the autumn on the spring foraging behavior of mule deer and cattle. J. Appl. Ecol. 17:69-84.

Willms, W., A.W. Bailey, A. McLean and R. Tucker. 1981. The effects of fall defoliation on the utilization of bluebunch wheatgrass and its influence on the distribution of deer in the spring. J. Range Manage. 34:16-18.

White, R.G. 1983. Foraging patterns and their multiplier effects on productivity of northern ungulates. Oikos 40:377-384.