Special Report 1052
June 2004

Range Field Day Report 2004

Current Forage and Livestock Production Research

Oregon State University
Agricultural Experiment Station

Figures 1 and 2. Affecting Beef Cattle Distribution in Rangeland Pastures with Salt and Water (David Ganskopp, pages 1-3).

Figure 1. Beef cow no. 126 wearing a GPS collar used to determine her precise location and activity at programmed intervals on the Northern Great Basin Experimental Range.

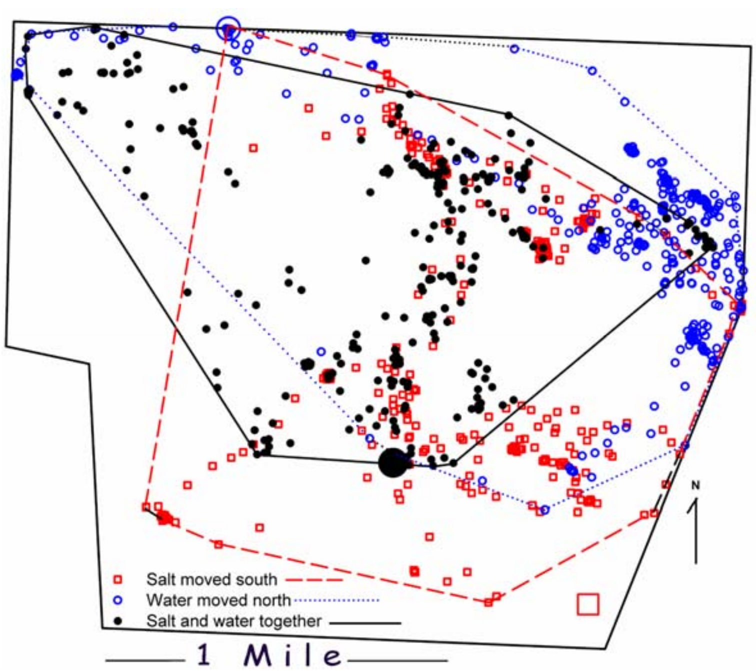

Figure 2. Locations of one cow in a 2,000-acre pasture sampled at 20-minute intervals with a collar-borne GPS unit in June and July 1999 near Burns, Oregon. Water and salt were moved among shared and separate locations within the pasture at weekly intervals.

Front cover photo: Steers grazing crested wheatgrass at the Northern Great Basin Experimental Range.

INTRODUCTION

In the past, Range Field Days have varied from specific topics such as water temperature to general topics such as rangeland ecology. The 1997 Range Field Day report was titled "The Sagebrush Steppe: Sustainable Working Environments." The bulk of the articles focused on general principles of livestock production and nutrition. Copies of that report are still available.

In the current report we chose to focus on forage and livestock production, but with more of an emphasis on current research. Some of the work has been ongoing for some time, while other research is in the early phases. We hope you find the information interesting and as always we are open to suggestions for future Range Field Day topics.

Sincerely,

Tony Svejcar
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TABLE OF CONTENTS

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AFFECTING BEEF CATTLE DISTRIBUTION IN RANGELAND PASTURES WITH SALT AND WATER

David Ganskopp

Summary

Water and salt are two of the tools most frequently used by livestock producers to encourage uniform use of forages by cattle across extensive rangeland pastures. The objective of this study was to evaluate the relative utility of salt and water manipulations for moving and holding cattle in specific portions of large pastures. When water was moved to distant and seldom used sectors of pastures, cattle moved to and remained near the newly placed water source. Cattle paid little attention to salt placement; they rarely returned to salt if water was moved to a new locale or seldom visited salt when it was moved to a distant location. Livestock producers can effectively control livestock distribution patterns in large pastures by either moving portable watering systems or closing and opening access to fenced water sources. While trace mineral salt is needed year round to rectify forage mineral deficiencies in cattle, there is little chance that salt placement can effectively correct serious livestock distribution problems under the conditions encountered in this study.

Introduction

To optimize income, livestock and forage producers typically strive to obtain uniform use of herbage over as much of their pastures as possible. Several of the problems associated with grazing animals in extensive settings, however, are related to uneven patterns of use across the landscape. In many environments, required elements like forage, water, minerals, shade, or resting areas are not uniformly dispersed about an area, and physiological constraints demand that herbivores center their activities around the most limited resource (Stuth 1991). Even when numbers of animals are matched with available herbage, mismanaged grazing may alter vegetation composition or damage sensitive resources where animals tend to congregate.

After fencing, water and salt are two of the most frequently used tools for affecting cattle distribution in large pastures. Cattle are obviously attracted to water in arid regions, but mixed results have been obtained with salt and mineral supplements. Ares (1953) found improved distribution and forage utilization after dispersing a cottonseed meal-salt mix, while Martin and Ward (1973) surmised that salt alone should not be expected to cure serious distribution problems. Others reported that salt had no influence at all on where cattle elect to forage (Bailey and Welling 1999). Sodium and chlorine are required elements for cattle, with lactating cows requiring about 0.10 percent sodium in their diets (Morris 1980). Chlorine requirements are not well established and chlorine deficiency is rare under normal conditions (Neathery et al. 1981, National Research Council 1996). Both sodium and chlorine are plentiful in soils of the western half of the United States, but most of our grasses contain insufficient salt to meet nutritional requirements of cattle (Ganskopp and Bohnert 2003).

The primary goal of this study was to evaluate the effectiveness of salt and water manipulations for altering cattle distribution in large (>2,000 acre) sagebrush/steppe pastures. This was accomplished by fitting cattle with Global Positioning System (GPS) collars to quantify their travels and activities while water and salt were provided at common or separate locations.

Experimental Protocol

The research was conducted in the three largest (2,000+ acres each) pastures on the Northern Great Basin Experimental Range. Three herds of 40 Hereford X Angus cow/calf pairs simultaneously grazed each pasture in June and July with two cows in each pasture wearing GPS collars configured to acquire the animal's position at 20-minute intervals (Fig. 1, *inside front cover*). With this schedule, 72 positions were obtained for each animal each day. The collars also contained motion sensors that allowed us to determine whether cattle were resting or grazing at each locale. One of three treatments was applied to each pasture at weekly intervals. These included: 1) salt and water together at a central point, 2) water moved to a distant locale with salt remaining in its original location, and 3) salt moved to a distant point with water remaining at its original location. Cattle were herded to each new site whenever salt or water were moved. Data analyzed included average distance from cattle to salt, average distance to water, total distance traveled per day, daily resting and grazing times, and the location of their centers of activity.

Results and Discussion

Cattle moved their centers of activity further (1,541 yards) when water was moved in a pasture than when salt (1,094 yards) was moved (Fig. 2, *inside front cover*). On average, cattle stayed within about 1,274 yards of water regardless of the resource moved (Table 1). This suggests that they followed the water tank to its new locale and remained nearby. Whenever salt or water were moved, the average distance of cattle from salt always increased, again suggesting there was little inclination for cattle to remain near salt.

If salt and water shared a common locale, cattle were found within 250 yards of salt and water 191 and 192 times within a week, respectively. When water was moved away from salt, cattle were near water 284 times and within 250 yards of salt only twice. Distance traveled per day (average = 3.59 miles), grazing time (11 hours per day), and resting time (10.1 hours per day) were unaffected by movements of salt or water. This implied that cattle did not increase their travel or alter their time spent grazing when water and salt were separated.

Management Implications

The movement of portable stock tanks or closing access to specific watering points within pastures is very effective at altering the distribution patterns of beef cattle on our arid rangelands. Cattle do not simply travel to distant water and return to their habitual foraging locations, but they alter their distribution to remain in the vicinity of water. Control of water placement may be used to 1) assure more uniform use of forages across large pastures over time, 2) attract cattle to areas not habitually used, 3) temporarily lure cattle away from seasonally sensitive portions of a pasture such as over-utilized areas or sage grouse nesting or strutting grounds, and 4) facilitate the gathering of herds in large pastures. Separations of salt and water sources will not cause cattle to alter their grazing times or expend more energy traveling each day. Finally, salt appears to be ineffective at markedly altering cattle distribution and will most likely not rectify a large-scale livestock distribution problem on sagebrush/steppe rangeland.

Due to some seasonal and year-round mineral deficiencies within our forages, however, trace mineral salt should still be furnished to rangeland cattle on a year-round basis. Dispersal of mineral sources around a pasture will certainly not cause harm. Mineral intake, however, will probably be highest where salt is placed near watering points.

Table 1. Average distance of cattle from water and salt, distance traveled per day, time spent grazing and resting per day, and area covered per day when water and salt occurred at a common locale and when water or salt were moved to a distant area in pastures in June and July 1999 near Burns, Oregon.

	Treatment			
Variable	water & salt shared location	water moved to distant area	salt moved to distant area	water & salt separated
distance (yd) to water	1142_a	1078_a	1601_a	1340_a
distance (yd) to salt	1126_a	2209_b	1648_c	1928_{bc}
distance (mi) traveled per day	3.61_a	3.43_a	3.72_a	3.58_a
grazing time (hr/day)	10.7_a	10.8_a	11.3_a	11.0_a
resting time (hr/ day)	10.2_a	10.6_a	9.5_a	10.0_a
area (ac) covered per day	785_a	573_a	1055_a	812_a
shift of center of activity (yd)	- -	1541_a	1094_b	- -

Values within a row sharing a common letter are not significantly different.

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WOLFY FORAGE: ITS EFFECT ON CATTLE DISTRIBUTION AND DIET QUALITY

David Ganskopp and David Bohnert

Summary

Among bunchgrasses, wolfy plants are clumps that have accumulations of both current and previous years' herbage. There are nutritional disadvantages to foraging on wolfy grasses and both cattle and wildlife will avoid grazing these plants. The objective of this study was to determine whether wolfy forage affected livestock distribution and forage utilization at landscape scales. By using cattle equipped with Global Positioning System (GPS) collars we found that foraging cattle avoided wolfy sections of pastures and favored areas supporting current year's herbage by about a 2.7 to 1 ratio. Indeed, wolfy areas of the pastures actually grew additional forage while cattle were present. Managers can use late-season heavy grazing, burning, or mowing to eliminate wolfy plants and encourage more uniform and complete use of their herbage by livestock in subsequent growing seasons.

Introduction

Four grasses common to the sagebrush/bunchgrass biome are well known for their propensity to become "wolfy." Native grasses include bluebunch wheatgrass, our premier native forage in the region, bottlebrush squirreltail, and Thurber's needlegrass. Crested wheatgrass, an introduced forage used in range reclamation efforts, also produces durable seed stalks that can persist within bunches for one to several years. These accumulations of persistent stems cause cattle to reject individual plants, and their herbage may go unused for many years (Fig. 1).

Earlier research at the Eastern Oregon Agricultural Research Center demonstrated that cattle are aware of even one cured stem in clumps of green grass, and they are about 40 percent less likely to forage on a wolfy plant than on one that does not have cured stems (Ganskopp et al. 1992, 1993). Many have reported preferential use by both wild and domestic animals of individual plants or patches of grass where old growth material has been removed by grazing or fire (Willms et al. 1980, Gordon 1988, Ruyle and Rice 1991, Ganskopp et al. 1992, Pfeiffer and Hartnett 1995). There has been little research, however, on how cattle respond to stands of wolfy forage at landscape levels. That being the case, the objective of this study was to determine where cattle grazed in pastures supplying mixtures of wolfy herbage and forage consisting of only current year's growth. This was accomplished by first conditioning portions of our pastures with heavy grazing, and then equipping cattle with GPS collars as they grazed the subsequent growing season to monitor their distribution patterns.

Experimental Protocol

Four pastures, each about 33 acres in size, were split with electric fence near the end of the growing season in mid-July 2000. One half of each pasture was designated as a "wolfy" treatment, while the other was designated a "conditioned" treatment. Over 7 days, about 75 cow/calf pairs were rotated through the conditioned portions of each pasture and left to forage until herbage was reduced to about a 1-inch stubble. No cattle were allowed in the wolfy sectors. Electric fences were removed, and in late May 2001 we sampled standing crop and forage and diet quality in both the wolfy and conditioned sectors (Fig. 2). Subsequently, three GPS-collared cattle were placed in each pasture. The GPS units were configured to ascertain a cow's position and activity level every 10 minutes for a total of 144 positions per day per animal. At that time, half of each pasture supported wolfy herbage, made up of current and last year's growth, and the conditioned half contained only green herbage with little to no standing dead stems.

Figure 1. A wolfy crested wheatgrass stand near Burns, Oregon. Herbage has been grazed from the uppermost portions of some wolfy bunches while bunches without residual straw are grazed to a short stubble. Substantial forage is wasted within wolf plants, because current year's growth is intermixed with older, cured materials that are nutritionally deficient and present a physical barrier to cattle grazing.

Figure 2. Wolfy and conditioned sectors of a crested wheatgrass pasture grazed by GPS-collared cattle on the Northern Great Basin Experimental Range near Burns, Oregon, in May 2001. Herbage in the wolfy sector (left of center), a mixture of last year's old material and the current season's growth, exhibited a lighter colored complexion. Grass on the conditioned side (right of center) was primarily current season's growth and contained little, if any, cured material.

Results and Discussion

When cattle were turned in, standing crop was about 484 pounds per acre in wolfy sectors and 180 pounds per acre in conditioned areas. By weight, about 50 percent of the wolfy herbage was cured material carried over from the previous growing season. Chemical analyses of standing crop (Table 1) found higher levels of crude protein (CP) and digestibility in the conditioned sectors (11 percent CP and 58 percent digestibility) than in the wolfy portions (6.5 percent CP and 47 percent digestibility). Diet quality of rumen cannulated steers confined to each treatment, however, was identical, averaging about 13 percent CP and 59 percent digestibility. This suggests that cattle are very good at sorting among old and new herbage and that they can, at least initially, extract a high-quality diet from stands of wolfy herbage.

Table 1. Forage quality indices of herbage and steer diets from conditioned and wolfy sectors of crested wheat grass pastures on the Northern Great Basin Experimental Range, near Burns, Oregon. in late May 2001. Bold treatment means beneath a common forage quality attribute and within a row are significantly different ($P \leq 0.05$).

	Forage quality indices							
	---percent---							
Forage	Crude protein		Neutral detergent fiber		Acid detergent fiber		Digestibility (ISDMD)	
Component	Wolfy	Conditioned	Wolfy	Conditioned	Wolfy	Conditioned	Wolfy	Conditioned
Standing crop	**6.5±0.2**	**11.3±0.3**	**66±1.5**	**60±0.6**	**38±1.2**	**30±0.3**	**47±1.8**	**58±0.6**
Cured herbage	1.9±0.2	--	74±1.0	--	47±0.9	--	39±0.5	--
Live herbage	11.1±0.2	11.3±0.2	61±1.0	61±0.8	30±0.3	29±0.4	56±0.6	58±0.6
Steer diets	13.1±0.7	14.1±0.4	62±2.6	58±1.4	29±1.1	27±0.6	57±1.9	61±1.2

We obtained a total of 12,096 coordinates from our GPS units. Across all activities, 41 percent of the coordinates occurred in the wolfy sectors and 59 percent were in the conditioned areas. Cattle grazed 45 percent of each day, and during that grazing time we averaged about 18 coordinates per day in the wolfy sectors and 49 coordinates in the conditioned portions of pastures (Fig. 3). Therefore, cattle preferred conditioned areas about 2.7 times more than wolfy areas when grazing. On the seventh day of the trial, however, the cattle switched, and we found them in the wolfy sectors 43 times and the conditioned areas 16 times. Quite possibly, the cattle were running out of feed in the conditioned sectors and were switching to the wolfy portions of the pasture to find sufficient forage. In hindsight, the trial should have been run for additional days to verify this hypothesis. When the trials were finished, herbage in the conditioned areas had a uniform grazed appearance, but evidence of grazing was difficult to see in the wolfy areas. Assessments after the trials detected a decrease of about 13 percent for standing crop in the conditioned portions of pastures, and herbage actually increased by about 10 percent in the wolfy sectors.

On average, cattle traveled about 2.71 miles per day. They also traveled slightly more each day as the trials progressed (2.25 miles on day 1 increasing to 2.87 miles on day 7). A logical inference is that travel may have increased in response to a dwindling forage supply. With the exception of their trips to water, cattle apparently did little traveling when they were not grazing. On average, 92 percent of their total travel was associated with their grazing activities.

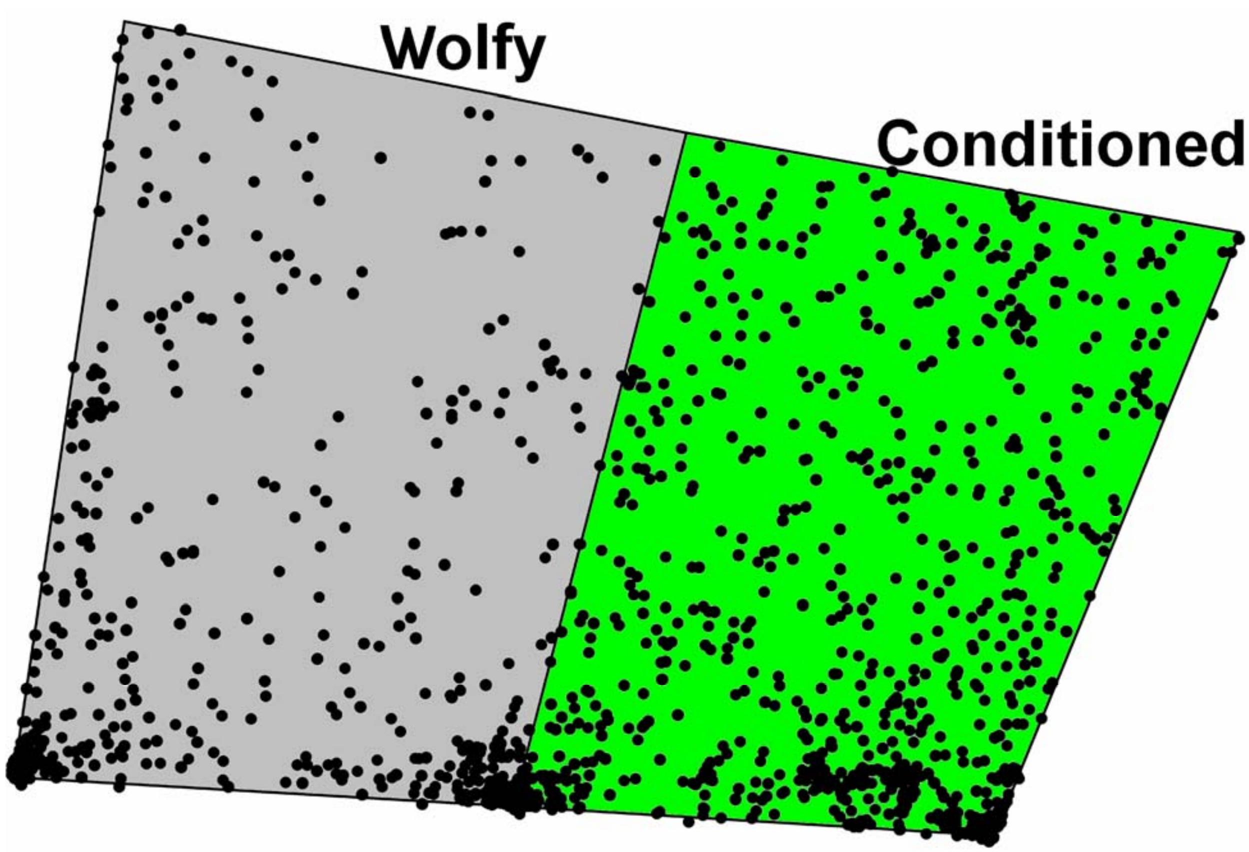

Figure 3. The distribution patterns of three GPS-equipped cattle (1,394 locations) as they grazed in a crested wheatgrass pasture supporting wolfy and conditioned sectors of forage over a 7-day period on the Northern Great Basin Experimental Range near Burns, Oregon, in 2001. In this figure, 394 locations occurred in the wolfy sector and 1,000 locations occurred in the conditioned area.

Management Implications

Given a choice, cattle exhibit a significant preference for conditioned portions of rangeland pastures as opposed to those areas supporting wolfy forage when they are grazing (about 2.7 to 1, respectively). Indeed, wolfy areas in pastures actually grew additional herbage while cattle were present.

The demonstrated preference for conditioned sectors of pastures may partially explain why livestock habitually use the same portions of pastures over successive years. Cattle quite likely are avoiding those locales that support a mixture of old and current season herbage and are selecting those areas and grasses where they do not have to sort between old and new growth. Some Canadian research has shown that there are some economically significant gains to be had from clean-up of wolfy crested wheatgrass stands (Romo et. al 1997).

Previous work at the Eastern Oregon Agricultural Research Center has shown that cattle forage less selectively after all grasses have cured. That being the case, the use of heavy grazing to clean out stands of wolfy plants will probably be more successful if it is applied late in the growing season after all herbage has cured. Other options for removing wolfy vegetation include mowing or prescription burning. Regardless of the treatment chosen, removing wolfy forage across the entire pasture will encourage more uniform use of all forage and more complete use of the newly available herbage by livestock or wildlife.

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STRATEGIC SUPPLEMENTATION OF CRUDE PROTEIN: AN ECONOMICAL MANAGEMENT STRATEGY FOR INTERMOUNTAIN COW/CALF PRODUCERS

David Bohnert

Summary

Cow/calf producers can use strategic supplementation to improve cow body condition scores (BCS), improve calf health, increase conception rates, and increase their operations' net income. Strategic supplementation of crude protein (CP) includes:

1) Determining the proper timing and amount of supplementation in relation to a cow's nutritional requirements and forage quality;
2) Choosing the most appropriate type and form of a CP supplement for a given situation and environment;
3) Grouping cows based on BCS to improve the efficiency of CP supplementation;
4) Using a CP supplement to alter cow distribution within a pasture to improve overall pasture utilization;
5) Reducing the frequency of CP supplementation to decrease associated labor and fuel costs.

Introduction

Supplemental CP is needed when the CP content of the forage base is insufficient for a cow to maintain a desired level of production. A review of forage quality research conducted at the Northern Great Basin Experimental Range west of Burns, Oregon indicates that forage CP can be expected to be below requirements for a cow/calf pair beginning in mid-June and for a non-lactating cow beginning in July (Fig. 1). Also, because the forage CP concentration drops with the digestibility of the grass, this results in lower intake and availability of nutrients for maintenance and production. This situation causes cows to lose weight and lower their BCS from mid-summer through weaning. However, intake and digestibility of nutrients can be increased if supplemental CP is provided, which means cows will be in better body condition entering the winter-feeding and/or calving season, will have stronger and healthier calves at calving, and will breed back faster than unsupplemented cows. Nevertheless, CP supplementation is expensive, and cow/calf producers should use a supplementation program that minimizes costs while allowing cows to meet an expected level of production.

The most efficient time to increase cow weight and BCS is the period from weaning to calving. Furthermore, providing adequate nutrition to the cow herd during this period is critical because approximately 80 percent of all fetal growth occurs during 3 months prior to calving (Anthony et al. 1986, Fig. 2). It is difficult, and cost prohibitive, to improve cow body condition following calving. This is because a cow's nutrient requirements are the greatest during lactation. Consequently, nutrition research at the Eastern Oregon Agricultural Research Center (EOARC) has focused on developing nutritional management strategies that reduce feed and supplementation costs while maintaining acceptable levels of performance during the pre-calving period. Strategic supplementation, specifically reducing frequency of CP supplementation, has yielded favorable results. I will discuss this and other relevant data pertaining to the ability of strategic supplementation to improve a cow/calf producer's profitability.

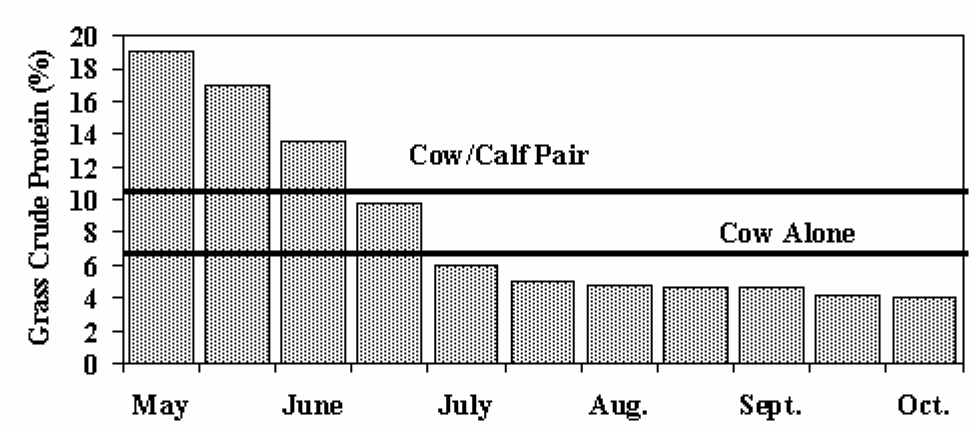

Figure 1. Estimated seasonal crude protein concentration of sagebrush-bunchgrass range and associated requirements of lactating and non-lactating cows adapted from Turner and DelCurto 1991.

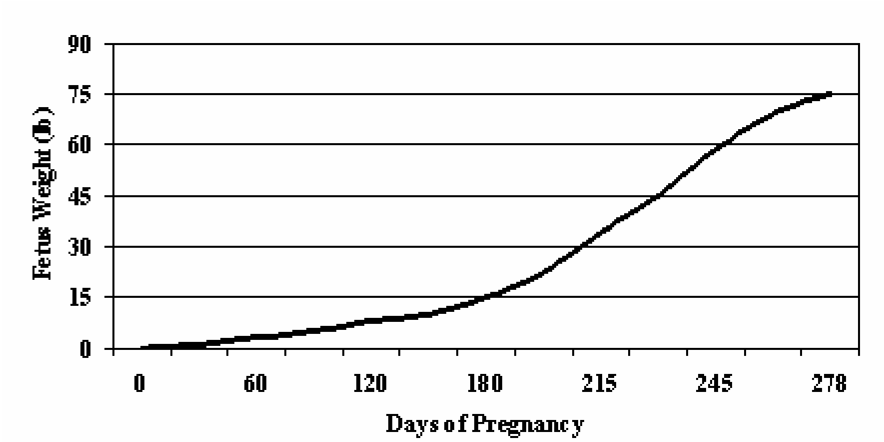

Figure 2. Fetus growth during gestation. Approximately 80 percent of all fetal growth occurs during the last 3 months of gestation adapted from Anthony et al. 1986.

Designing a Crude Protein Supplementation Program

Is CP supplementation necessary?

The first step in preparing a CP supplementation program is to determine if CP supplementation is necessary. This involves obtaining an estimate of forage CP concentration that can be obtained from historical records or, preferably, from analysis of a representative sample of the forage source to be used (pasture, meadow hay, grass seed straw, etc.). Once this information has been collected, along with cow CP requirements that can be obtained from NRC (1984) tables available at your local extension office, a cow/calf producer can determine if CP supplementation is necessary to meet an expected level of performance.

How do I choose a CP supplement?

Most sources of supplemental protein can be grouped into four broad categories. These are:

1) oilseeds and oilseed meals (cottonseed, soybean, canola, sunflower, etc.);
2) animal and grain byproducts (fishmeal, feather meal, brewers grain, distillers grain, etc.);
3) legume hays (primarily alfalfa);
4) non-protein nitrogen (urea and biuret).

In addition, most CP supplements are usually in one of two forms. These are dry feeds (meals, cubes, cakes, pellets, dry or pressed blocks, alfalfa hay, etc.) and liquid feeds (molasses-mixes, hardened molasses blocks or tubs, etc.). Consequently, cow/calf producers have many choices to consider when selecting a source and form of supplemental CP. However, there are a few considerations that beef producers should incorporate into their decision-making process when deciding on a form of supplemental CP. These include supplement delivery method and cost per pound of supplemental CP.

Supplement delivery method

Choosing a supplement delivery method determines if a CP supplement will be hand-fed or self-fed. Hand-feeding involves regularly providing a supplement to animals in a manner that allows rapid consumption (alfalfa, soybean meal, cottonseed cake, etc.), whereas self-feeding involves periodically providing large quantities of supplement with the assumption that animals will consume the supplement in consistent, controlled amounts over an extended period of time (salt mixes, molasses mixes, blocks, tubs, etc.). Self-fed supplements normally require less labor compared with hand-fed supplements; however, they are usually more expensive per pound of CP and normally have a greater variation in supplement intake per animal.

Cost per pound of crude protein

Calculating the cost per pound of CP allows a beef producer to determine which protein source/form is most economical to purchase for use as a protein supplement. For example, assume a beef producer has the option of purchasing alfalfa hay (17 percent CP, $85/ton) or soybean meal (54 percent CP, $250/ton) as a CP supplement and has the facilities and equipment to feed both properly. Which protein supplement is the most economical? Initially, the beef producer may assume alfalfa hay is the best choice; however, when the cost per pound of CP is calculated, it becomes clear that soybean meal (2,000 pounds * 54 percent CP = 1,080 pounds CP; $250/1,080 pounds CP = $0.23/pound CP) is actually cheaper than alfalfa hay (2,000 pounds * 17 percent CP = 340 pounds CP; $85/340 pounds CP = $0.25/pound CP) when expressed per pound of CP. Therefore, soybean meal would be the most economical CP supplement.

Crude Protein Supplementation Strategies

Split the cow herd into low and adequate BCS groups

One of the most cost effective CP supplementation strategies is to split the cow herd into groups based on BCS (1-to-9 scale; 1 being thin and emaciated and 9 being overly fat or obese). This can be a hassle depending on resource (pasture and labor) availability; however, it is worthwhile if planned properly. It is recommended that the cow herd be split into at least two groups, one containing cows with adequate BCS (5 and above) and one containing cows with low BCS (4 and less). This is because research from Texas A&M University (Lamp 1995) has shown cows with a BCS of 4 or less at calving and breeding will not breed back fast enough to maintain a 365-day (one calf per year) calving interval (Fig. 3). Also, compared with thin cows, cows with a BCS of 5 or greater have improved calf health, survivability, and weaning weights. The bottom line is that thin cows cost cow/calf producers money (Table 1). A reduced pregnancy rate, resulting in fewer calves at weaning, is responsible for the largest reduction in net income.

By grouping cows based on their BCS, a cow/calf producer can strategically provide supplemental CP to the thin cows that require additional nutrients. In contrast, if all cows are fed together in one group, cows with an adequate BCS consume supplemental CP that would be better utilized by thin cows. This means that the cows with an adequate BCS are being overfed while the thin cows are being underfed, which is inefficient and results in a more expensive supplementation program, not to mention a decreased number of calves at weaning.

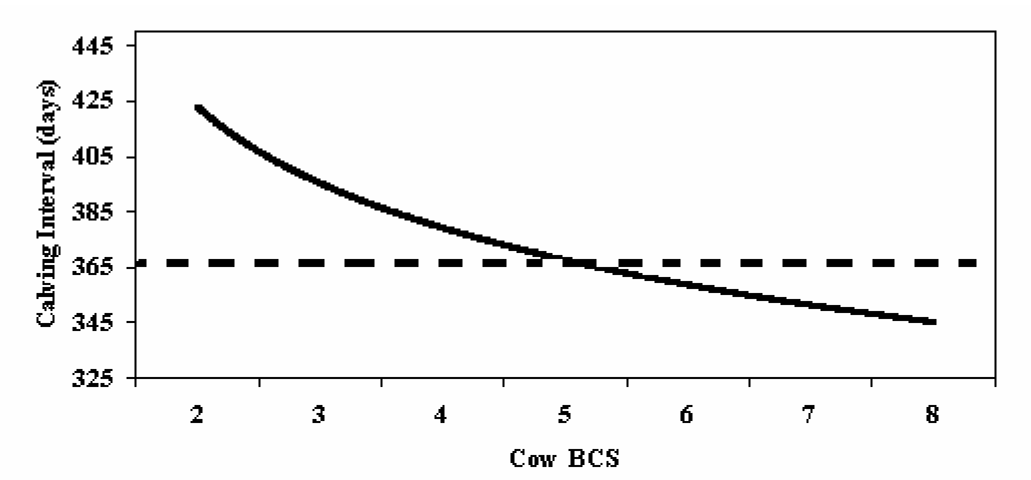

Figure 3. The effect of cow body condition score at breeding on calving interval. The dotted line indicates a 365-day calving interval (one calf per year; adapted from Herd and Sprott 1986).

Table 1. Lost net income per thin cow (BCS 3 or 4) compared to a cow with a BCS of 5 (adapted from Lamp 1995).

	Calf price per hundredweight				
	$60	$70	$80	$90	$100
Cow BCS	Lost net income per thin cow				
BCS 4	$27.82	$39.84	$51.85	$63.86	$75.88
BCS 3	$51.51	$75.53	$99.56	$123.58	$147.60

Supplement placement can affect cow grazing distribution

Strategic placement of a CP supplement can lure cattle to areas of a pasture infrequently grazed, thus potentially improving grazing distribution. A Montana study evaluated the ability of strategically placed dehydrated molasses blocks (30 percent CP) to attract cows to underutilized rangeland and improve grazing distribution (Bailey and Welling 1999). Molasses blocks were moved every 7 to 10 days to areas normally not grazed because of rough terrain and/or distance from water. Grass utilization within 200 yards of supplements was increased from 15 to 20 percent compared with the same area before supplement placement. In contrast, areas of similar terrain and distance from water, with no molasses block present, were found to have no evidence of grazing following a similar period of time. This suggests that strategic placement of CP supplements can increase the total usable area of rangeland pastures, potentially increasing AUM's available to the cow/calf producer.

Decrease supplementation frequency to reduce labor and fuel costs

Providing a CP supplement is expensive. Costs include the supplement and labor, fuel, and equipment associated with supplement delivery. Other than determining the type and quantity of a CP supplement to purchase, a beef producer has little control over supplement cost. However, a beef producer does have significant control over labor and associated supplement delivery costs. Therefore, recent research has attempted to develop CP supplementation strategies that decrease the costs associated with supplement delivery while maintaining acceptable levels of performance.

Research at EOARC has demonstrated that cattle consuming low-quality forage can be provided a natural, high-protein source of supplemental CP (soybean meal, cottonseed meal, etc.) as infrequently as once every 6 days without adverse effects on nutrient intake and digestibility, grazing behavior, or cow performance (Fig. 4) compared with providing a supplement daily (Bohnert et al. 2002, Schauer et al. 2003). In addition, with proper planning and management, CP supplements containing sources of non-protein nitrogen, such as urea and biuret, can be provided every other day with no difference in performance compared to daily supplementation. Likewise, alfalfa can be provided two or three times a week with results similar to daily supplementation.

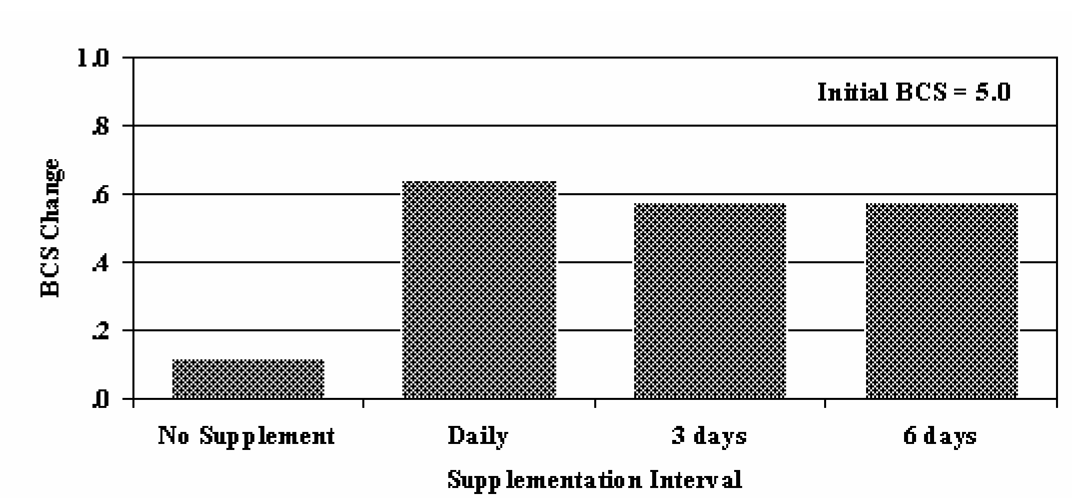

Figure 4. The effect of CP supplementation interval on body condition score (BCS) change of cows consuming low-quality forage during the 3 months prior to calving (adapted from Bohnert et al. 2002).

The primary advantage of infrequent over daily supplementation is the decreased costs associated with supplement delivery. The potential savings in time and labor of infrequent supplementation are provided in Table 2. Assuming that a cow/calf producer will require 3 gallons of fuel ($1.70/gallon) and 2.5 hours of labor ($7.05/hour) for each day supplemental CP is provided, total labor and fuel costs over a 30-day period are approximately $680, $340, $230, and $115 for supplementation every day, once every 2 days, once every 3 days, and once every 6 days, respectively. Based on these figures, infrequent supplementation can reduce total costs associated with supplement delivery from 50 to 80 percent compared with providing a supplement daily. Another way of evaluating the benefits of infrequent supplementation is to look at the time that is available to do something other than providing supplemental CP every day. Using the scenario above, a cow/calf producer would have an additional 37.5, 50, or 62.5 hours available each month for other projects if supplementation occurred every other day, every 3 days, or every 6 days, respectively, compared with daily supplementation (Table 2).

Table 2. Decreased labor and fuel costs associated with infrequent supplementation over a 30-day period.

	Supplementation interval			
Item	Daily	2 days	3 days	6 days
Fuel cost ($)[a]	153.00	76.50	51.00	25.50
Labor cost ($)[b]	528.75	264.38	176.25	88.12
Total costs	681.76	340.88	227.25	113.62
Benefit (hours)	0	37.5	50.0	62.5
Benefit ($)	0	340.88	454.51	568.14

[a] Fuel cost calculated as 3 gallons/supplementation day at $1.70/gallon.
[b] Labor cost calculated as 2.5 hours/supplementation day at $7.05/hour.

Conclusion and Management Implications

The most appropriate method of CP supplementation for one cow/calf producer may not work for all producers. Once CP supplementation is deemed necessary, producers should use economics, the value of convenience, and potential effects on cattle distribution within pasture to determine their most appropriate form of CP supplementation. For example, alfalfa hay may be more economical per pound of CP than a molasses-based block; however, blocks are continuously accessible and do not have to be provided as frequently as alfalfa hay. The difference in cost of alfalfa hay and the molasses block (per pound of CP) is considered the cost of convenience. In addition, continuously available supplements, such as blocks, tubs, liquid mixes, etc., may be more appropriate if altering cattle distribution within a pasture is a consideration. However, infrequently providing a more traditional source of CP (alfalfa hay, soybean meal, cottonseed meal, etc.) can decrease the time and labor associated with supplementation, thereby decreasing the cost of convenience between more expensive sources of CP. Also, infrequent supplementation of traditional sources of CP allows for strategic placement of supplement within a pasture, which may alter cattle distribution.

Infrequent supplementation of CP to cattle consuming low-quality forage can reduce labor and fuel costs by as much as 83 percent compared to daily supplementation without affecting nutrient utilization and performance. However, producers should consider the use of an extension agent or nutritional consultant when designing an infrequent supplementation regime because certain sources of supplemental CP (i.e., urea-containing supplements) can cause toxicity concerns, potentially resulting in death of livestock, if not managed properly.

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INTERANNUAL PRODUCTIVITY IN BURNED AND UNBURNED WYOMING BIG SAGEBRUSH-GRASSLAND

Jon Bates

Summary

Interannual climate variability has a huge impact on forage production in the sagebrush steppe. Forage production tends to be positively correlated with higher crop year (Sept–May) precipitation, but other factors are also important. Temperature, timing of precipitation, and soil nutrient availability also influence forage production. In this study, herbaceous production was evaluated in burned and unburned sagebrush steppe over a 6-year period. Herbaceous production was estimated every 2 weeks by clipping. By clipping frequently we have been able to track current years' production trends and develop a better understanding of how peak production fluctuates at the community and functional group (e.g., perennial grasses, perennial forbs) level.

As expected, dry years generally produce less forage than wet years. However, we also recorded higher productivity in a drought year than in a preceding year when precipitation was higher. Clearly, other environmental factors are interacting with precipitation to affect sagebrush steppe productivity. In dry years, peak production tended to occur earlier in the growing season than in years when precipitation was above or near average. The burn increased herbaceous production when compared to the unburned treatment in the second and third year after fire. During the drought years (fourth–sixth after fire) differences in productivity were minimal between the burned and unburned plant communities.

Introduction

Herbaceous production in the sagebrush steppe is highly variable across years. The variability is linked to the amount and timing of precipitation received over the winter and early spring (Sneva 1982). Past work has focused on the relationship of total peak production and crop year (Sept–May) precipitation. Total peak production is assumed to occur when perennial bunchgrasses are in flower. Because of the focus on bunchgrass productivity, relationships between precipitation and other species and functional groups are not as well quantified. Because of differing phenological development, peak production of other plants in the community may be undervalued.

In this study, we monitored herbaceous productivity every 2 weeks during the course of 6 growing seasons (Apr–Aug). Determining productivity through the growing season provided an index of not only peak community production but peak production for other plant functional groups as well. We placed plants into functional groups based on plant type and growth cycles. We separated current year's growth from total standing crop to quantify year effects to annual productivity. We also compared productivity between burned and unburned treatments.

Methods

The study was located at the Northern Great Basin Experimental Range (NGBER), 35 miles west of Burns, Oregon. The plant community was dominated by Wyoming big sagebrush and native bunchgrasses. Bunchgrasses included Thurber's needlegrass, Idaho fescue, bluebunch wheatgrass, and Junegrass.

Treatments consisted of a burned and unburned community. The burn was conducted in late summer 1997. The burn area was approximately 5.8 acres in size; the unburned community was 7.5 acres. These fields have not been grazed since 1994.

Herbaceous biomass was clipped to a 1-inch stubble height every 2 weeks from mid-April through August in 1998–2003. Biomass was clipped by plant functional group. Functional groups were Sandberg's bluegrass, large perennial bunchgrasses, perennial forbs, annual grass, and annual forbs. Frames used for clipping were 1 yd^2. We clipped 25 frames per treatment (25 in the burn and 25 in the unburned). Sampling was performed to obtain uniform distribution within each treatment. Biomass was dried at 48°F for 48 hours, then weighed to obtain dry matter weight.

After drying, biomass was sub-sampled and separated into non-active (dead) and current year's growth (live) standing crop. Live standing crop provides an indication of the current year's production. The percentage of dead and live biomass was used to adjust biomass values for each clipping date.

Results

Yearly variability

Herbaceous production was highly variable among years in both burned and unburned treatments (Fig. 1 and Table 1). The burn treatment stimulated herbaceous production when compared to the unburned treatment in the second and third year post-treatment (Figs. 1–3 and Table 1). Since the fourth year post-burn, production has not differed between the burned and unburned treatments.

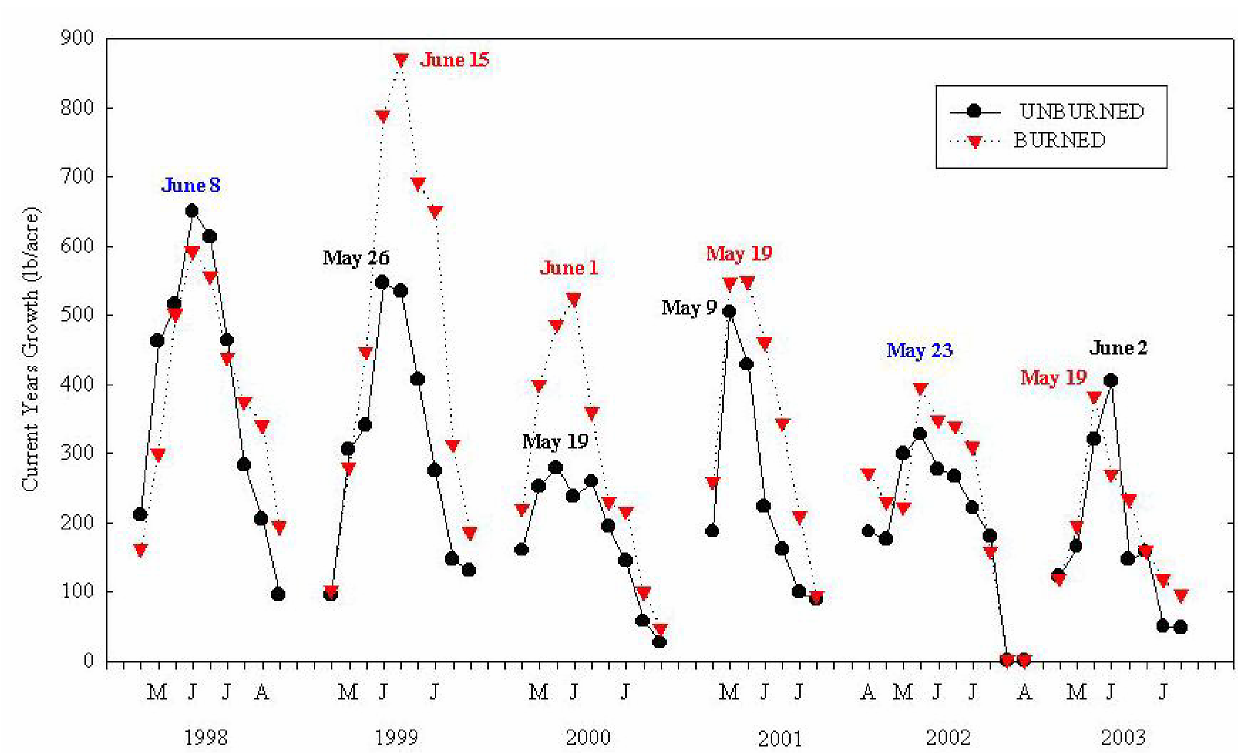

Figure 1. Growing season production (live green biomass, lb/acre) at Northern Great Basin Experimental Range (NGBER) for years 1998–2003. Dates in blue are peak production dates for both burned and unburned fields. Dates in black are peak production dates for the unburned field. Dates in red are peak production dates for the burned field.

Table 1. Standing crop (current year's growth [live] and dead) at peak perennial grass production, showing percent of live vegetation and peak date of production.

Year	Perennial bunchgrasses		Sandberg's bluegrass		Perennial forb		Annual forb		Total biomass			Percent of live vegetation	Date of peak perennial grass production
	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Total		
	lb/acre											%	
1998													
Unburned	428[1]	418	- - -	- - -	150[2]	0	- - -	- - -	579	418	997	58	June 8
Burn	320	24	- - -	- - -	206	0	- - -	- - -	526	24	551	95	June 8
1999													
Unburned	360	392	62	106	52[2]	8	- - -	- - -	475	520	995	48	June 15
Burn	627	339	35	95	113	29	- - -	- - -	777	463	1240	63	June 15
2000													
Unburned	183	467	1	73	46	6	1	3	230	549	779	30	June13
Burn	354	443	8	57	99	23	5	13	465	537	1003	47	June 1
2001													
Unburned	272	466	92	57	56	12	28	0.1	450	530	979	46	May 9
Burn	350	414	44	78	82	13	13	7	488	512	1000	49	May 22
2002													
Unburned	191	430	42	48	56	37	8	4	293	507	800	37	May 23
Burn	240	407	25	26	76	44	11	9	351	484	836	42	May 23
2003													
Unburned	202	367	47	63	78	3	34	10	359	443	802	45	June 2
Burn	155	276	1	73	49	2	5	35	208	386	594	35	June 16

[1] Grass production in 1998 includes both perennial bunchgrasses and Sandberg's bluegrass.
[2] Forb in 1998 and 1999 includes both perennial and annual forbs.

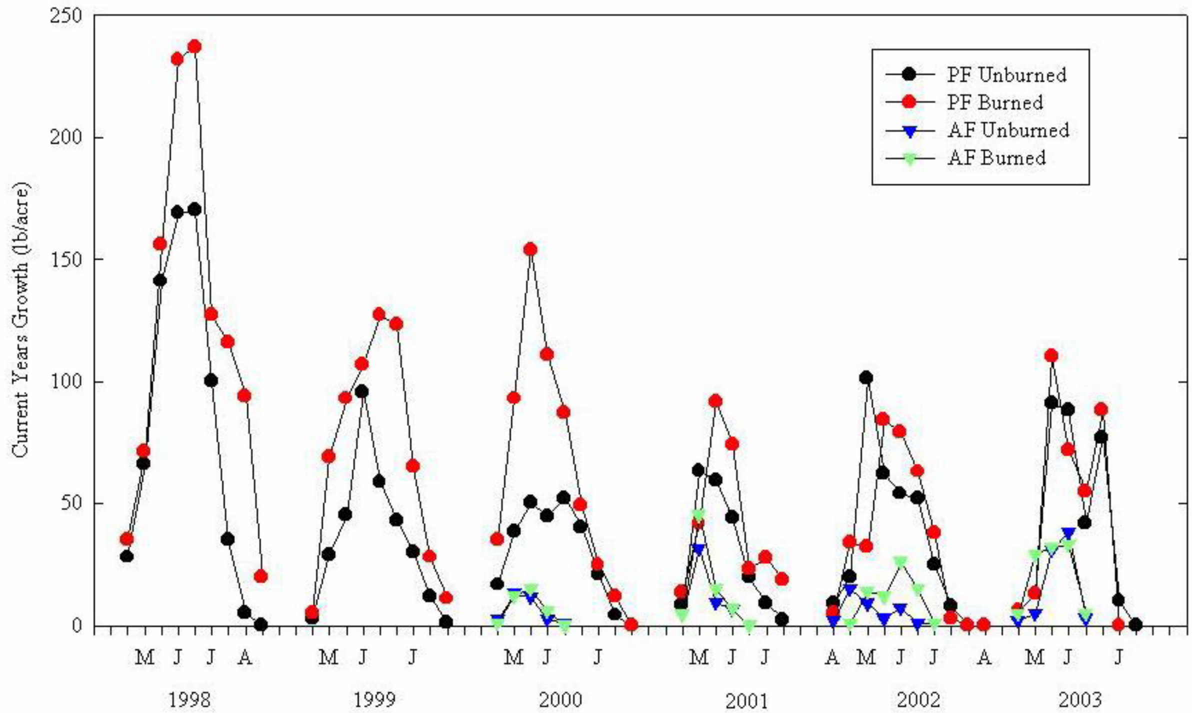

Figure 2. Growing season production (current year's growth, lb/acre) of perennial bunchgrasses (PG) and Sandberg's bluegrass (Poa) at the Northern Great Basin Experimental Range for years 1998–2003. Perennial bunchgrass production in 1998 includes production of Sandberg's bluegrass.

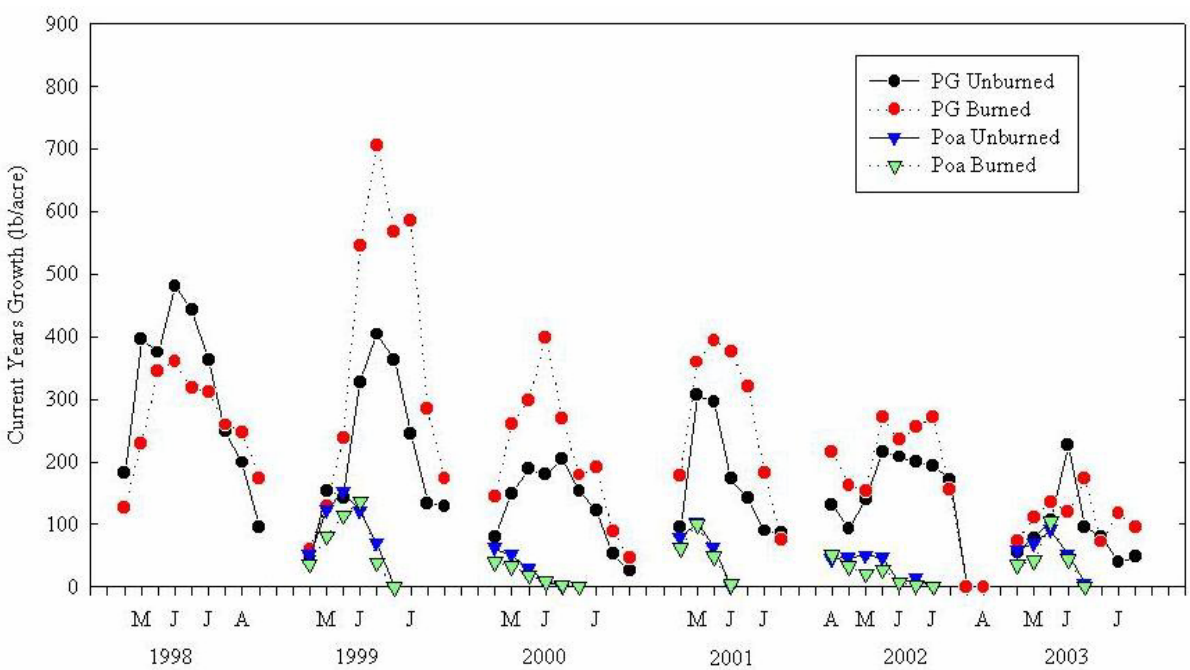

Figure 3. Growing season production (current year's growth, lb/acre) of perennial forbs (PF) and annual forbs (AF) for burned and unburned treatments at the Northern Great Basin Experimental Range for years 1998–2003. Forb production values in 1998 and 1999 include both perennial and annual forb production.

Peak production and peak standing crop

Date of peak production was highly variable among years and differed between the treatments (Fig. 1). Peak production differed between the burned and unburned treatments in 3 of the 6 years of the study.

There were also differences based on how peak production was calculated. The traditional manner of estimating community peak production is to clip plots when perennial grasses are at peak productivity. However, in the unburned treatment there was a poor relationship between dates of peak community productivity and the dates when peak perennial grass production was reached. Dates of community peak production matched peak perennial grass production only half of the time (compare peak production dates shown in Fig. 1 and Table 1). Thus, using peak perennial grass production underestimated community peak production in 3 of the 6 years.

In the burn treatment, peak perennial grass production agreed with community peak production 83 percent of the time. Only in the sixth year of the study was actual community level production underestimated when using perennial grass production to set the date of peak productivity.

Because these plots have not been grazed, there is a considerable build-up of standing dead material (Table 1). Except for 1998, dead material in total standing crop always exceeded 50 percent in the unburned treatment at peak production. Standing dead material in the burn has increased as a percentage of total standing crop over time.

Functional group production

Functional group productivity and peaks of production varied across years and among the treatments (Figs. 2 and 3). Peak production of Sandberg's bluegrass and perennial and annual forbs tended to occur earlier than peak production of perennial bunchgrasses.

Precipitation influences

Crop year precipitation is shown in Fig. 4. Drought is defined as prolonged dry weather when precipitation is less than 75 percent of the average. Drought occurred from 2001 to 2003. Correlations between annual precipitation and community and functional group productivity were not consistent. Crop year precipitation accounted for 72 and 90 percent of the variation in perennial forb production for unburned and burned treatments, respectively. For the other functional groups and the whole community, especially the burn treatment, predicting peak production using crop year precipitation was not as strong a relationship (predictability ranged from 6 to 55 percent). In the unburned treatment, crop year precipitation predicted 45, 51, 45, and 55 percent of the variation in peak production of perennial grasses, Sandberg's bluegrass, annual forbs, and the whole community, respectively.

Discussion and Management Implications

Generally, a positive relationship was found for crop year precipitation and herbaceous production. The strength of this relationship varied among the functional groups. Others have found both weak (Passey et al. 1982, Sneva 1982) and strong (Sneva 1982, Sneva and Britton 1983) correlations between crop year precipitation and herbaceous production. Possible reasons for lack of strong correlations include underestimation of precipitation as snow, difficulty in accounting for the effects of precipitation timing, and interacting factors such as temperature and soil nitrogen. Work at NGBER suggests that nitrogen availability influences response to precipitation (Sneva and Britton 1983). They found that after 3 years of above-average precipitation, forage production decreased because available soil nitrogen was lacking for plant uptake. The burn treatment may result in some nutrient limitation. Production in the burn has declined since the second year post-burn as precipitation has declined. However, total production and functional group production were less in the burn than unburned in 2003, the sixth year after fire. This is an interesting result since sagebrush competition was removed with burning. These results suggest that factors other than just precipitation, such as nutrient limitation, may be affecting site productivity.

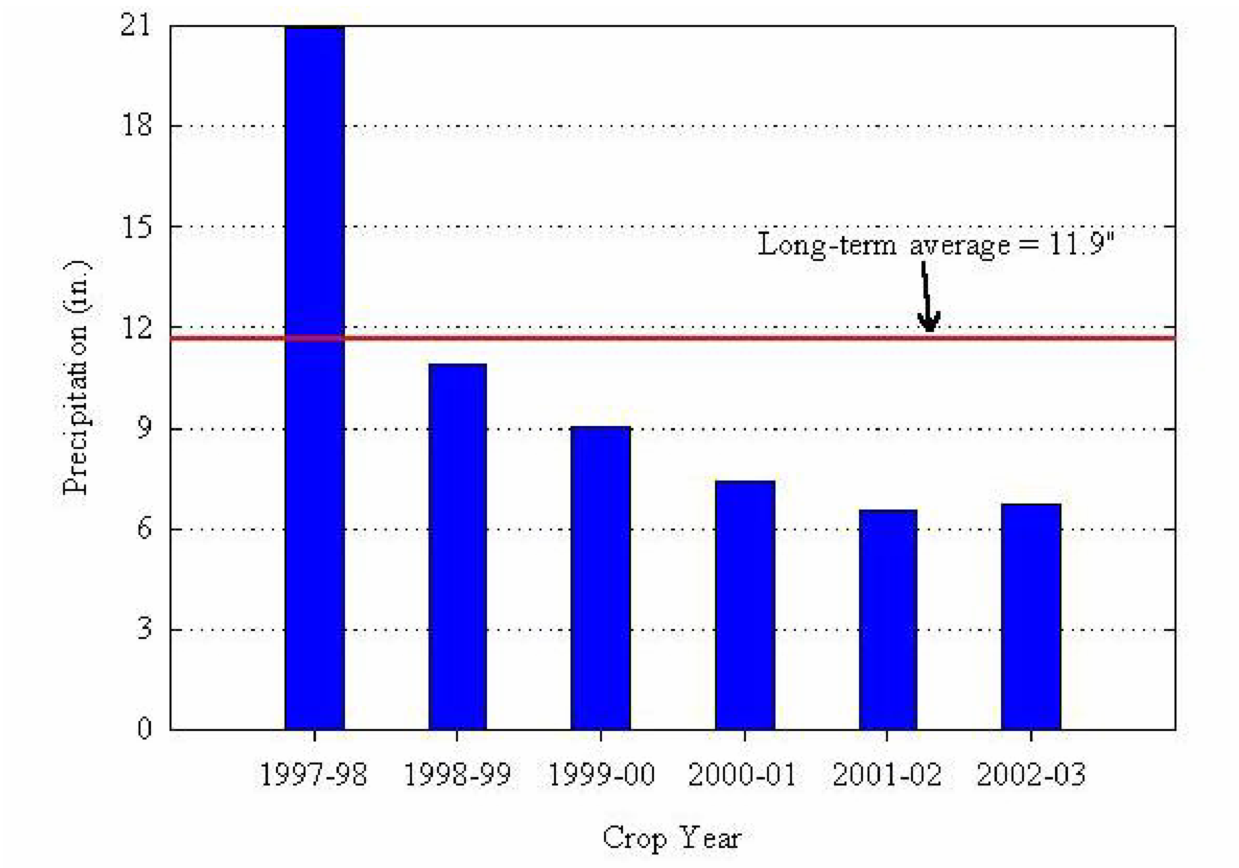

Figure 4. Crop year precipitation (Sept–June) at the Northern Great Basin Experimental Range.

Results also demonstrate that production in the sagebrush steppe is inherently erratic and is not solely dependent on precipitation. For example, we recorded a consistent decline in production in the unburned treatment between 1998 and 2000. Even though precipitation did not differ much between 1999 (10.9 inches) and 2000 (9.2 inches), production was reduced by almost half in 2000 (Fig. 1). The following year, 2001, crop year precipitation was only 7.5 inches (a drought year), but peak production was almost twice as high in 2001 compared to 2000 (Table 1 and Fig. 1).

The results suggest that land managers face a significant challenge in separating the effects of management from that of climate. This becomes particularly important in making ecological assessments and detecting trends in rangeland condition. Too often changes in forage production and other ecological indicators in the sagebrush steppe are implicitly assumed to be a result of management decisions rather than the effects of climate.

We intend to continue this study into the foreseeable future. This year should provide a good indicator of how herbaceous productivity, at the community level and by functional group, responds after drought.

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FORAGE PRODUCTION IN A CUT JUNIPER WOODLAND

Jon Bates, Tony Svejcar, and Rick Miller

Summary

Western juniper expansion into the sagebrush steppe diminishes forage production, reduces plant and wildlife diversity, and negatively impacts hydrologic function. One goal of removing invading juniper woodlands is to restore herbaceous productivity. This study assessed forage production and plant successional dynamics for 12 years following juniper cutting. Biomass, cover, and density of understory species were compared between cut (CUT) and uncut woodland (WOODLAND). We also compared production and composition among three zones in the CUT treatment: old canopy, under juniper debris, and interspace.

Total biomass, cover, and density increased in the CUT treatment over time and were greater in the CUT when compared to the WOODLAND. Biomass increased from 322 lb/acre in 1993 to 966 lb/acre in 2003 in the CUT treatment. Biomass was 10 times greater in the CUT versus the WOODLAND. Densities of perennial grasses have remained stable at 10 plants/yd^2 since 1997. Herbaceous biomass and cover did not change between 1997 and 2003, indicating that by the sixth year after cutting, remaining open areas had been occupied.

Vegetation response in the CUT depended on zonal location. Cheatgrass dominated debris and canopy zones between the fifth and tenth year post-cutting. However, by 2003 perennial grass biomass was two times greater than annual grass in these zones. In interspace zones, perennial grasses were the dominant functional group with higher cover and biomass than other functional groups. Retaining juniper debris on this site did not benefit establishment and growth of perennial grasses compared to interspace and canopy zones.

Juniper cutting successfully restored forage production in this plant community and reduced the number of acres required per AUM from 33 to 3. For livestock operations, increasing the forage base improves management flexibility and expands available management options, which have both economic and ecological benefits. Increasing the forage base permits other juniper-dominated areas to be treated with proper post-treatment rest. Increasing the forage base in upland plant communities may also take pressure off riparian zones.

Introduction

The expansion and development of western juniper woodlands is of significant concern in the northern Great Basin. Western juniper is currently found on about 8.6 million acres in the northern Great Basin. Woodland dominance can result in reduced wildlife diversity, generate increased erosion and runoff, and reduce understory productivity and diversity of shrub-steppe plant communities. To address these undesirable consequences, western juniper has been controlled through a variety of treatments. Prescribed fire and hand cutting using chainsaws are two of the primary methods used to control juniper. Control of juniper increases availability of soil water and nutrients and thus commonly results in large increases in biomass and cover of herbaceous species. However, there is a lack of longer-term assessments after treatment by either fire or cutting in the western juniper system.

The purpose of this study was to evaluate longer-term vegetation changes after cutting of western juniper. This study was conducted from 1991 through 2003 on private land on Steens Mountain in southeast Oregon. We compared changes in herbaceous and shrub composition between cut and uncut woodlands. In the CUT treatment we also compared herbaceous response among three zones, and evaluated how quickly shrubs and juniper reestablish and develop after cutting. The three zones were 1) the interspace that was not influenced by juniper litter; 2) the old canopy, where juniper litter accumulated prior to cutting; and 3) the juniper debris zone, under cut trees where juniper litter accumulated.

Study Area and Methods

The study site was a big sagebrush/Thurber's needlegrass community and was located on Steens Mountain, in southeast Oregon. Elevation at the site is 5,100 ft and aspect is west facing. Juniper has dominated this site, eliminating the shrubs and suppressing herbaceous species. Tree canopy cover averaged 26 percent and tree density averaged 101 trees/acre. Bare ground was 90 percent in interspace zones (Fig. 1, *inside back cover*). Sandberg's bluegrass was the dominant understory species. Main species found on site include Thurber's needlegrass, bluebunch wheatgrass, and squirreltail. Annual precipitation at the Malheur National Wildlife Refuge weather station located near the study site averaged 10.8 inches over the past 34 years.

The experimental design was a randomized block with four blocks and two juniper treatments (CUT and uncut [CONTROL] woodland). Blocks were 2 acres in size and were established in summer 1991. Vegetation was characterized prior to tree cutting in September 1991. All trees in half of each block were cut using chainsaws, thus providing one CONTROL and one CUT plot per block. All cut juniper trees were left in place.

Shrub and tree cover were measured by line intercept along 5 100-ft m transects in 1993. In 1997 and 2003, shrub and tree cover were measured by line intercept along 3 165-ft transects.

Herbaceous density was measured in 1991–1997 and 2003. Biomass and canopy cover were measured in 1991–1993, 1996, 1997, and 2003. Density and canopy cover of herbaceous species were measured inside 2.2-ft^2 frames. Sampling in the CUT woodland was spatially stratified into three zones: interspace, canopy, and debris. In WOODLAND, zones were stratified into interspace and canopy. In 1993, herbaceous biomass was sampled in each CUT plot using 25 1-yd^2 frames per plot. Biomass was not sampled by zone in 1993 or 1996. In June 1997 and 2003, herbaceous biomass was sampled by zone in each plot using 25 1-yd^2 frames. Herbage was clipped to a 1-inch stubble height by functional group. Functional groups were Sandberg's bluegrass, perennial bunchgrasses (e.g., Thurber's needlegrass, bluebunch wheatgrass, squirreltail), perennial forbs, annual grasses (cheatgrass and Japanese brome), and annual forbs. Clipped herbage was dried at 48°F for 48 hours prior to weighing. To compare treatments across all the years, zonal biomass values in 1997 and 2003 were weighted by area occupied by each zone to obtain a treatment mean.

Results

Juniper cutting on this site successfully restored herbaceous cover and productivity, and density of desirable perennial grasses (Fig. 2, *inside back cover*). Total herbaceous plots biomass (Fig. 3), density (Fig. 4), and cover (Table 1) increased ($p < 0.001$) in the CUT over time and were greater ($p < 0.001$) in the CUT when compared to the WOODLAND. Biomass increased from 322 lb/acre in 1993 to 966 lb/acre in 2003 in the CUT treatment (Fig. 3). Biomass was 10 times greater in the CUT versus the WOODLAND in all years. Perennial grass density was about 5 times greater in the CUT compared to the WOODLAND (Fig. 4). In the CUT, densities of perennial grasses have remained stable at about 10 plants per yd^2 since 1997.

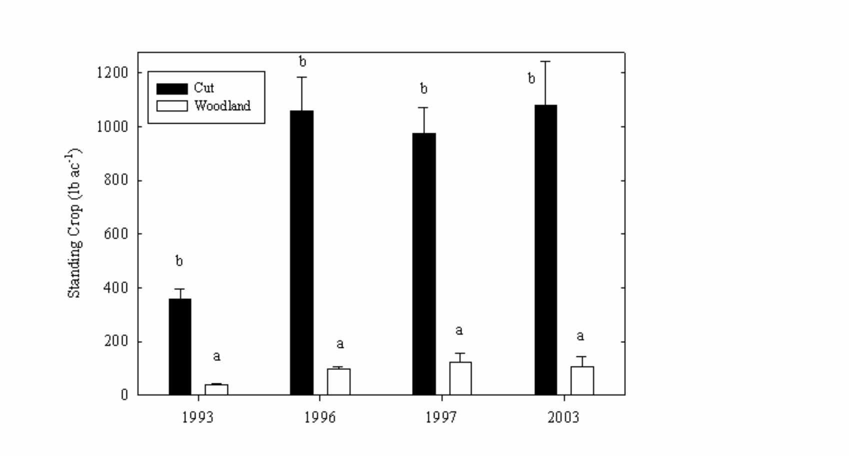

Figure 3. Herbaceous standing crop biomass (lb/acre) in cut and woodland treatments in 1993, 1996, 1997, and 2003. Data are in means plus one standard error. Different lower case letters indicate significant differences between treatments.

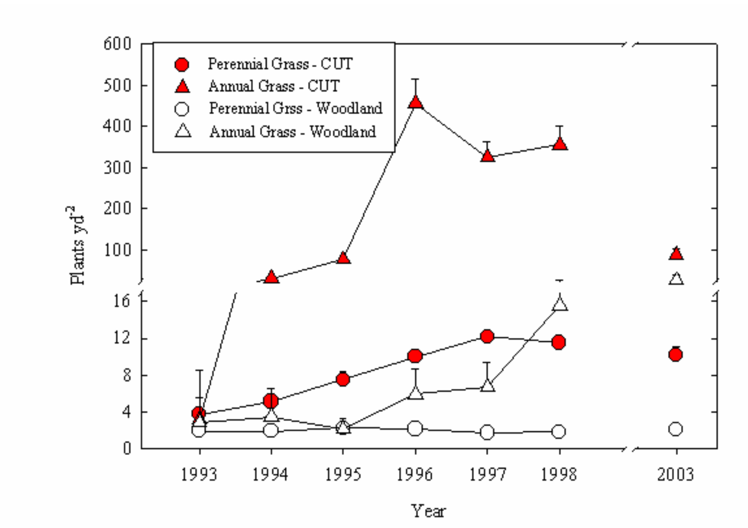

Figure 4. Densities of perennial grass and annual grass species. Values are weighted by zone to obtain treatment means. Values are in means plus one standard error.

Within the CUT treatment herbaceous composition has changed over time and has been influenced by zonal location. In interspace zones of the CUT treatment, perennial grasses were the dominant functional group with higher cover and biomass than other functional groups in all years (Figs. 5 and 6). However, between 1996 and 2001, cheatgrass dominated litter deposition areas (dead tree canopies and debris zones) (Figs. 5 and 6). The increase in cheatgrass in these areas may have been due to more favorable seedbed characteristics and increased nutrient and water availability. However, by 2003, cheatgrass decreased significantly ($p < 0.001$) in debris and canopy zones with corresponding increases in perennial grass biomass and/or cover. In 2003, perennial grass biomass was two times greater than annual grass in canopy and debris zones. There may be several reasons for the decline in cheatgrass: dry conditions the past several years may have reduced cheatgrass establishment and growth, less favorable seedbed properties occur as litter is incorporated into the soil and exposure increases, and competition from perennials has increased.

Discussion and Management Implications

Juniper cutting resulted in a large increase in the forage base. In this study, acres required per AUM were reduced from 33 to 3 acres. From a livestock production standpoint, management flexibility and options are increased. Options include increasing stocking rates, keeping livestock in fields longer and thus permitting other juniper-dominated areas to be treated with proper post-treatment rest, and increasing flexibility in grazing systems using rest-rotational and deferment scheduling. Increasing the forage base in upland plant communities may take pressure off riparian zones.

Important ecological benefits include reducing runoff and soil erosion, and restoring habitat that is lost for many wildlife species when juniper dominates plant communities. Juniper cutting also increases soil water availability, and thus extends the growing season by 4 to 8 weeks (Bates et al. 2000). This permits herbaceous plants to complete their growth cycle from a production and reproductive standpoint. Increased seed production is a result of an extended growing season and in this study resulted in increased establishment of new plants.

Biomass and perennial grass density did not change significantly between 1996–1997 and 2003. This would indicate that it took 5 to 6 years for understory vegetation to fully develop and occupy the site.

Sagebrush and other shrubs have increased steadily since juniper was cut, but shrub cover remains far below potential for this site (Table 1). Juniper has also reestablished in the CUT treatment (Table 1) from the small individuals that were not controlled in the initial treatment and from juniper seed. Juniper density in 2003 was 200 trees per acre. These trees were either seedlings or juveniles less than 18 inches tall. Prior to cutting it only took 100 trees per acre to dominate this site. Unless controlled, there are presently enough young trees that, when mature, will dominate the site within 50–60 years.

We found that retaining juniper debris on site did not benefit establishment and growth of perennial grasses when compared to interspace and canopy zones (Figs. 5 and 6). The main perennial grass that moves into litter deposition zones is squirreltail. Other perennial grasses, especially Thurber's needlegrass, have been slow to establish and develop, if at all, in old canopy and debris zones. Production in debris zones has been less than in adjacent interspace and canopy zones. Debris represents about 20 percent of the area. This debris has extremely low decomposition rates. Juniper debris also increased annual grass presence on site although observations the past year indicate that cheatgrass may be declining.

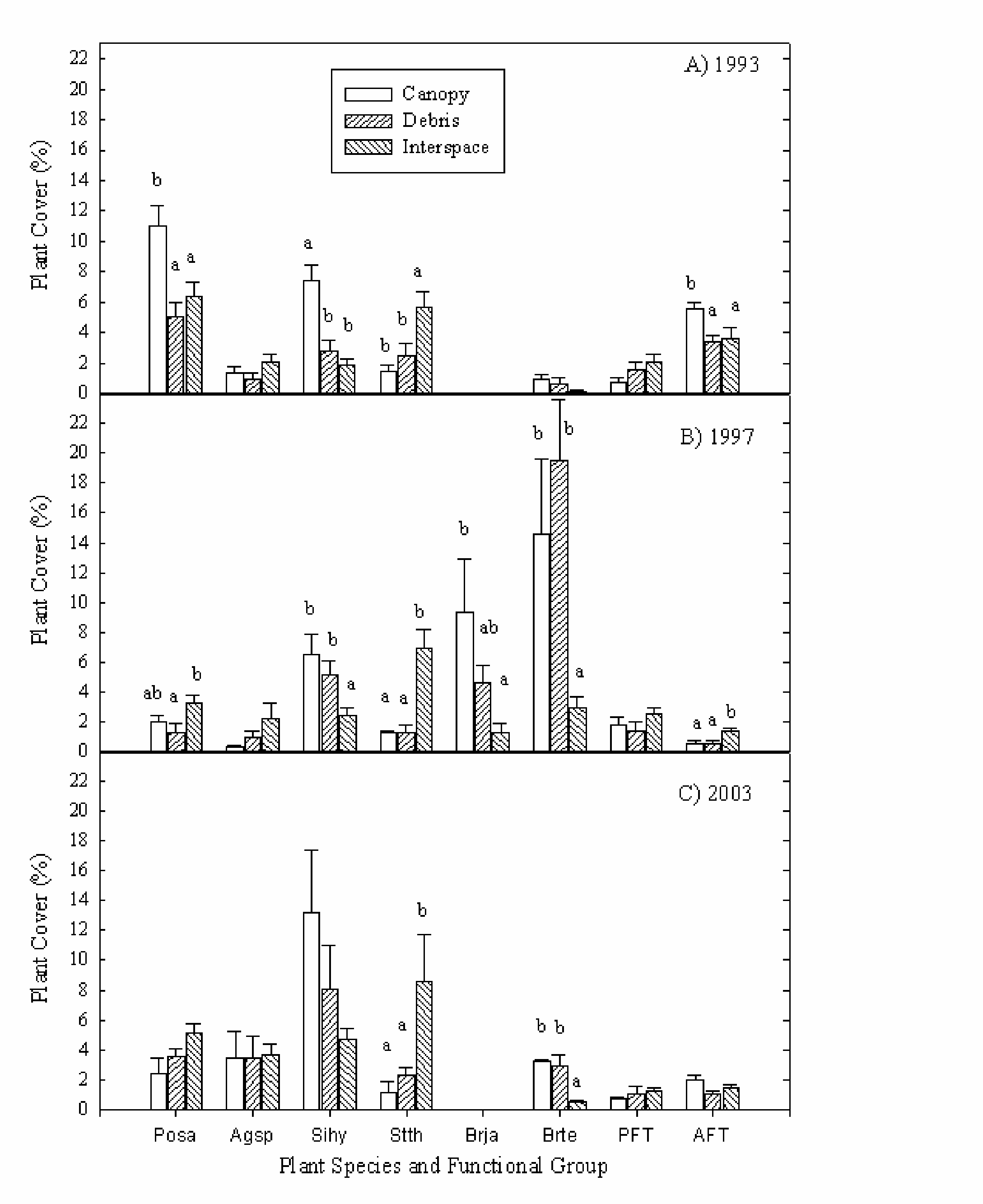

Figure 5. Herbaceous cover of plant species and functional groups (percent) by zone in (A) 1993, (B) 1997, and (C) 2003. Data are in means plus one standard error. Different lower case letters indicate significant differences between treatments. Species and functional groups are Posa (Sandburg's bluegrass) Agsp (bluebunch wheatgrass), Sihy (bottlebrush squirreltail), Stth (Thurber's needlegrass), Brja (Japanese brome), Brte (cheatgrass), PFT (perennial forbs), and AFT (annual forbs).

Table 1. Comparisons of cover (%) and tree and shrub density values collected on Steens Mountain, Oregon, as affected by juniper cutting treatment.

Year & treatment	Tree cover	Tree density[1]	Shrub cover	Shrub density	Litter[2]	Herbaceous cover	Bareground & rock
	%	no. ac^{-1}	%	no. ac^{-1}	%	%	%
1993							
Cut	0.0 ± 0.0 a[3]	85.4 ± 30.5 a	0.0 ± 0.0	24.4 ± 22.1	31.4 ± 2.4	19.0 ± 1.5 b	49.2 ± 1.6 a
Woodland	27.6 ±1.6 b	318.5 ± 27.3 b	0.0 ± 0.0	11.2 ± 8.9	27.5 ± 1.7	4.3 ± 0.5 a	68.2 ± 2.8 b
1997							
Cut	0.2 ± 0.2 a	129.7 ± 29.3 a	1.4 ± 1.0	887.5 ± 686.4 b	34.5 ± 2.0	29.3 ± 3.2 b	37.2 ± 2.6 a
Woodland	24.7 ± 2.0 b	335.4 ± 39.1 b	0.0 ± 0.0	14.8 ± 14.8 a	29.7 ± 1.8	5.5 ± 0.7 a	65.8 ± 3.5 b
2003							
Cut	0.7 ± 0.3 a	222.2 ± 32.7 a	2.5 ± 1.2	630.0 ± 309.0 b	34.1 ± 1.9	26.4 ± 2.5 b	39.6 ± 1.5 a
Woodland	24.7 ± 2.0 b	312.0 ± 14.8 b	0.0 ± 0.0	14.8 ± 14.8 a	28.7 ± 1.7	5.7 ± 0.9 a	66.3 ± 2.6 b

[1] Tree density includes all trees from seedling to large mature trees. Mature tree density averaged 101 trees ac^{-1}.
[2] Litter in cut plots includes litter in intercanopy, debris, and canopy zones. Litter in woodlands is primarily under trees with less than 2% in the interspace zones.
[3] Different lower case letters indicate significant differences between treatment means within a column ($p < 0.05$).

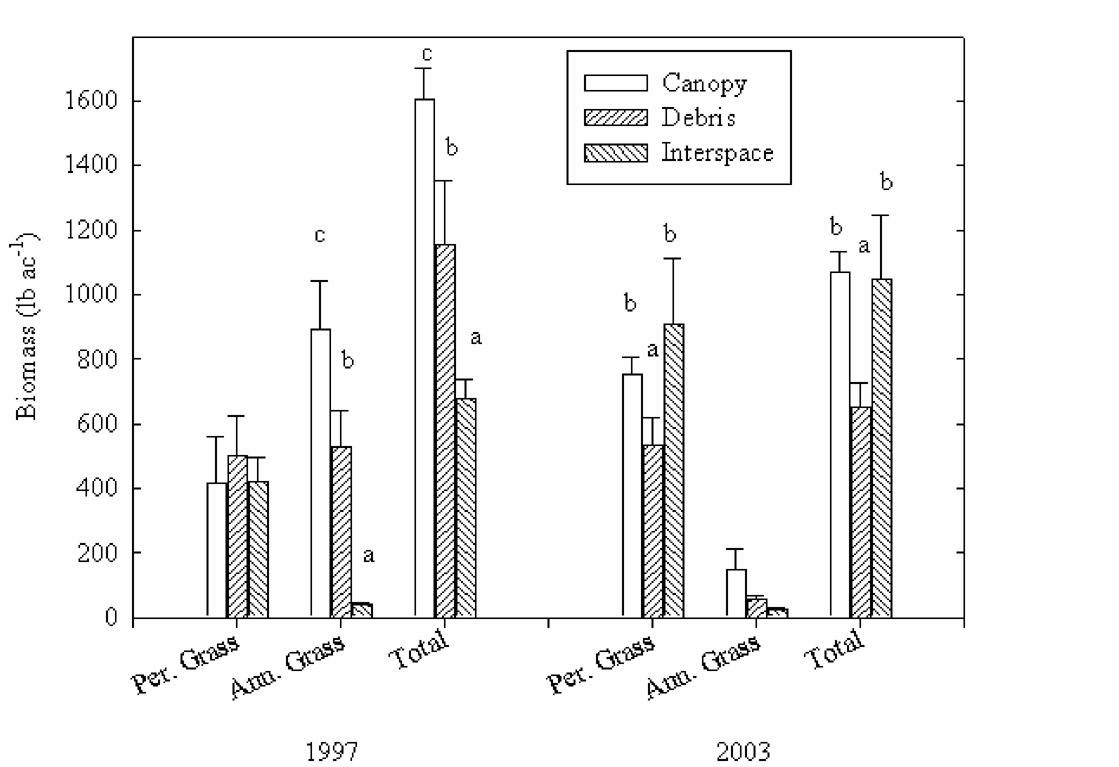

Figure 6. Functional group herbaceous biomass (lb/acre) by zone in 1997 and 2003. Data are in means plus one standard error. Different lower case letters indicate significant differences among zones. Functional groups are perennial grass (Per. Grass), annual grass (Ann. Grass), and total biomass (Total).

Conclusions

Temporal dynamics (changes over time)

1. Cutting juniper increased herbaceous cover and biomass within the first 2 years following treatment, but it took 5 years for peak production to be reached.
2. Production of perennial grasses has continued to increase with steady reductions in production of other functional groups.
3. Shrub species were establishing by the fourth year post-cutting but remain a minor component of the system 12 years after cutting.
4. Juniper has rapidly reestablished on site with densities sufficient to re-dominate the community in 40–50 years.

Spatial dynamics (change over space)

1. Succession in interspace zones was driven by species from the original plant community, with dominance by perennial grasses over the 12-year study period. Thurber's needlegrass and bluebunch wheatgrass established preferentially in interspace zones.
2. Succession in debris and canopy zones has been a function of both original species (initial floristics) and a few invaders (relay floristics). Annual grasses dominated mid-successional stages in debris and litter zones but not interspace zones.

3. Squirreltail was the main perennial grass to establish in debris and litter zones and has dominated later successional stages. Debris and litter zones have not been conducive to establishment of other perennial grasses at this point.

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PRODUCTION AND REGROWTH OF RIPARIAN SEDGE/GRASS COMMUNITIES

Chad Boyd and Tony Svejcar

Summary

Stubble height regulations are frequently used to manage livestock grazing of herbaceous riparian vegetation. The objective of this study was to determine the impact of clipped stubble height and time of clipping on production and regrowth of herbaceous riparian vegetation. In June and July of 2000–2003, 2.2-ft^2 experimental plots were clipped to stubble heights of 2, 4, or 6 inches, and paired control plots were left unclipped. All plots were clipped to ground level in October and regrowth was calculated by comparing clipped and control plots. Results indicate that 1) height of regrowth was associated positively with stubble height and 2) regrowth was less with July compared to June clipping. Annual production was higher with July (3,430 lbs/acre) compared to June (3,169 lbs/acre) clipping but did not vary by clipping height. Production values for clipped plots were higher than for unclipped plots, indicating compensatory production in response to defoliation. Timing and intensity of defoliation were reliable predictors of regrowth and production performance. Most clipping height by time combinations produced end-of-season heights sufficient to meet current federal stubble height requirements (i.e., 4–6 inches). Our results provide insight on the timing and intensity of defoliation that will allow for adequate regrowth to meet different management objectives. However, other factors such as stream channel morphology, animal selectivity, and annual weather variation will need to be considered.

Introduction

End-of-growing-season herbaceous stubble height is an important consideration for managers of riparian areas grazed by livestock. Development of stubble height guidelines in systems grazed by livestock is a difficult task involving knowledge of 1) the relationship between stubble height and sediment deposition (Skinner 1998); 2) the regrowth dynamics of riparian vegetation following grazing (i.e., can the vegetation regrow by the end of the growing season to meet desired conditions) (Clary 1995); 3) the interaction of stubble height and streambank degradation (Clary and Leininger 2000); and 4) special habitat considerations such as optimizing stubble height for wildlife needs (e.g., Neel 1980). Previous research indicates that both timing and intensity of defoliation can impact production and regrowth of herbaceous riparian vegetation (Pond 1961, Clary 1995, Sheeter and Svejcar 1997). However, only a limited number of studies (e.g., Clary 1995) have addressed the simultaneous effects of timing and intensity of defoliation, or the influence of environmental factors on regrowth and production dynamics of riparian communities. Our objective was to determine the impact of timing and intensity of defoliation on regrowth and above ground production of herbaceous riparian species.

Methods

Experimental design

Our study incorporated a randomized block design with split plots within blocks. We utilized three small (<8 ft width) C-channel (Rosgen 1994) streams in Harney County, Oregon. On each creek we selected four 16- by 33-ft research sites (blocks, Fig. 1). Sites ranged in elevation from 3,900 to 4,600 ft. Electric fencing was established around each block in April of 2000 and data were collected during 2000–2003. Plant community types varied across and within streams and included sedge, rush, and grass-dominated stands. Predominant sedges included Nebraska sedge and wooly sedge, dominant grasses were Kentucky bluegrass and redtop, and baltic rush was the most common rush. Treatments were applied within macroplots (split plots) located within 3 ft ("CLOSE") and 13 ft ("FAR", Fig. 1) from the edge of the stream. In all cases, the FAR plots remained within the stream's zone of hydrophytic influence. We located 2.2-ft^2 paired treated (clipped) and control (unclipped) plots in each macroplot (Fig. 1). Each plot pair was randomly assigned to a clipping date and stubble height combination (Fig. 1).

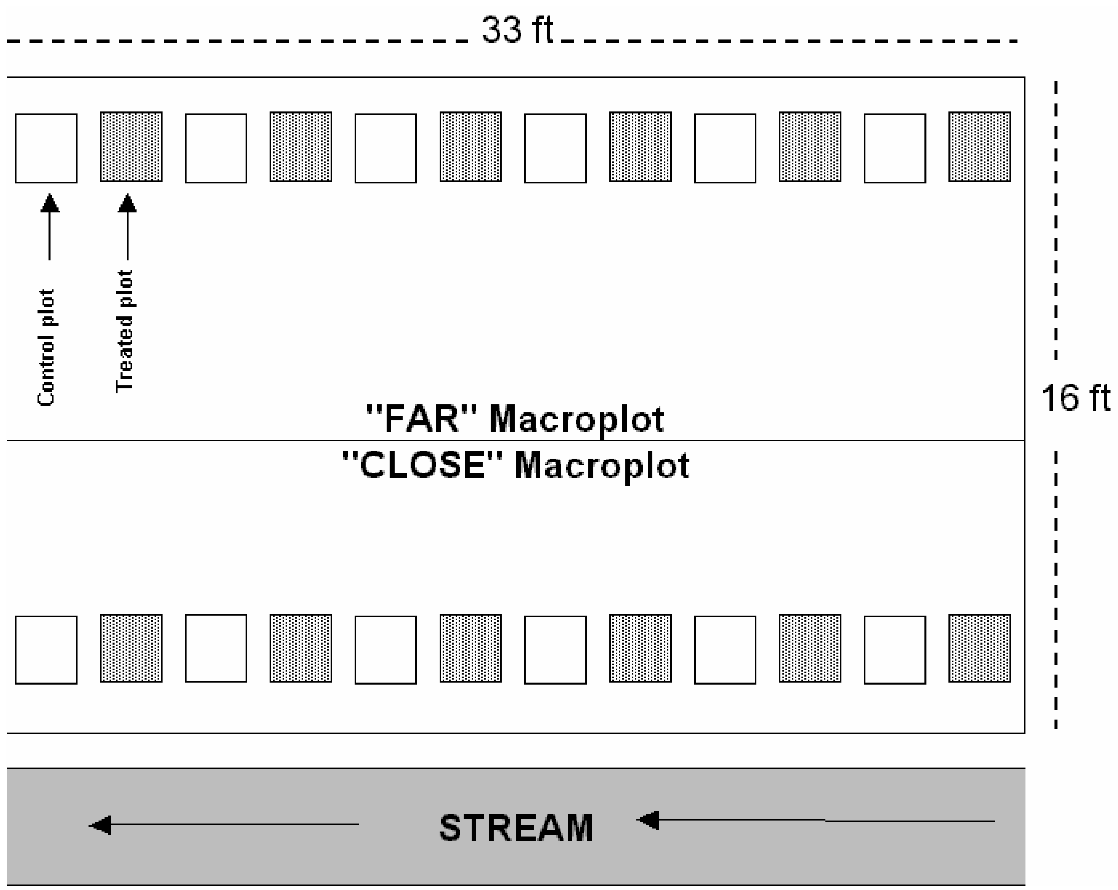


Figure 1. The basic block design used along streams in Harney County, Oregon. There were four such sites used along each of three, C-channel streams.

Clipping treatments

Plots were clipped to 2, 4, or 6 inches in either late June or late July. Most herbaceous species were in early flower at the time of the June clipping and seeds were nearing maturity by the July clipping. All plots, including the controls, were clipped to ground level at the end of each growing season (Oct), and regrowth and annual (season long) aboveground production were determined. Regrowth was calculated by dividing the end-of-growing-season (Oct) height of the treated plots by that of their paired control plot. We calculated annual production of treated plots by summing the weight of clipped vegetation across the growing season. Annual production in treated plots was also calculated as a percentage of paired control plots.

Statistical analysis

Data were statistically analyzed for clipping height, time, and distance from stream channel effects on annual production and percent regrowth by height using mixed model analysis of variance (PROC MIXED, SAS 1999). Clipping height, time, and distance from stream were designated as fixed effects. Main effects and interactions were considered significant at $\alpha = 0.10$. When significant main or interactive effects were found we assessed differences in treatment means using the LS MEANS (SAS 1999) procedure at $\alpha = 0.10$.

Results

Height regrowth was influenced by the interactive effects of clipping height by clipping time, and clipping height by distance from active stream channel. Values for height regrowth were generally less than 50 percent (of control plots) and increased with increasing clipping height (Fig. 2). Distance from stream had little impact on height regrowth with the exception of the 2-inch clipping height, where the CLOSE plots had 13 percent greater regrowth than FAR plots (Fig. 2a). Plots clipped in June had greater height regrowth at all clipping heights compared to those clipped in July, with an average increase (across clipped stubble heights) of 34 percent for June clipping (Fig. 2b). End-of-growing-season height (Fig. 3) ranged from a low of 3.5 inches for the 2-inch, FAR, July clipping treatment to 7.5 inches for the 6-inch, FAR, June clipping treatment (Fig. 3). End-of-season height for unclipped plots averaged about 15 inches. Annual production varied by time of clipping and increased from 3,169 lbs/acre for June clipping to 3,430 lbs/acre for July clipping (Fig. 4a). Weight of vegetation harvested at the time of clipping made up a greater proportion of annual production for plots clipped in July than in June (Fig. 4a). Production as a percent of control plots was influenced by year of clipping and ranged from 123 percent in 2000 to 108 percent in 2001 (Fig. 4b). Values for 2000 were 14 and 10 percent higher than 2001 and 2002, respectively (Fig. 4b).

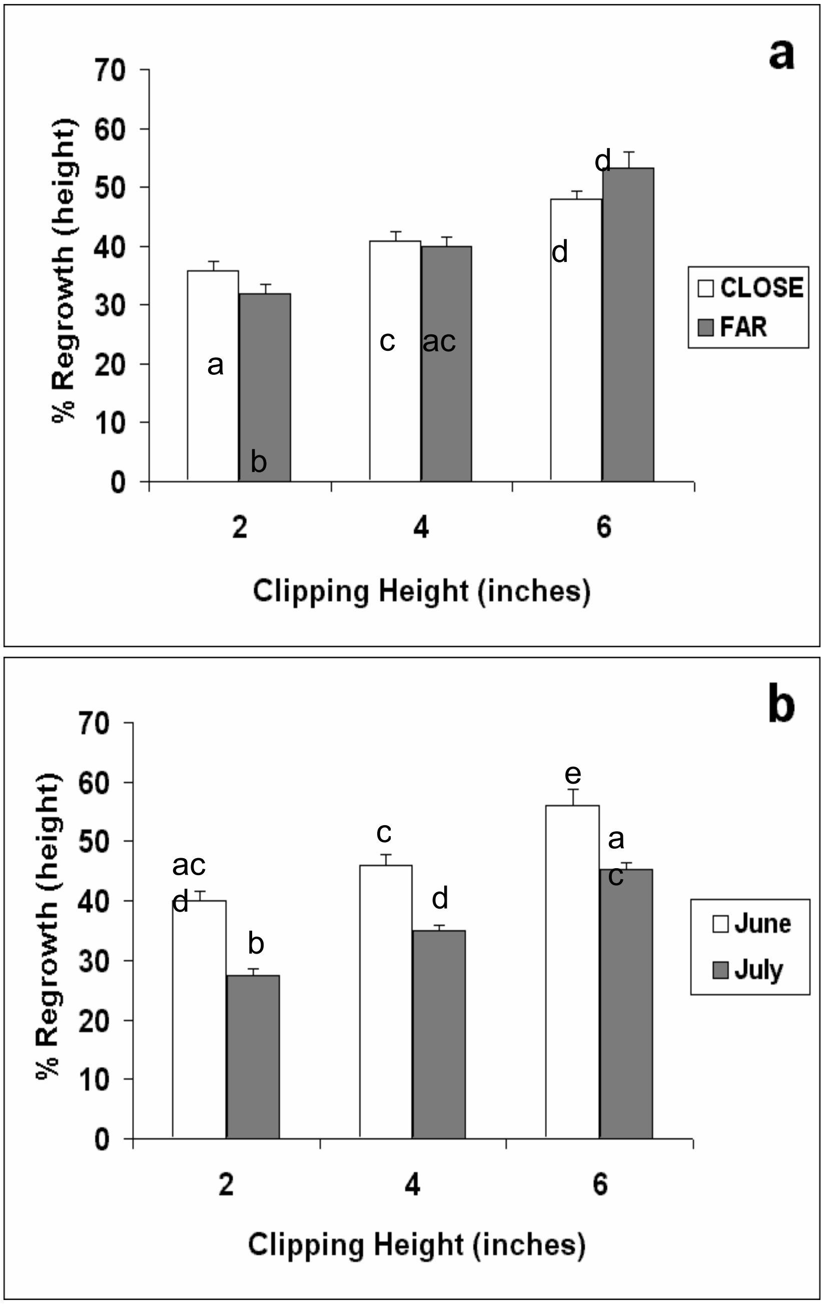


Figure 2. The influence of clipping height and a) distance from active stream channel and b) clipping time, on percent height regrowth for herbaceous riparian plants in plots located along streams in Harney County, Oregon. Regrowth was calculated by dividing end-of-growing-season (Oct) height of experimental plots by that of paired control plots. Bars without a common letter are different at $\alpha = 0.10$

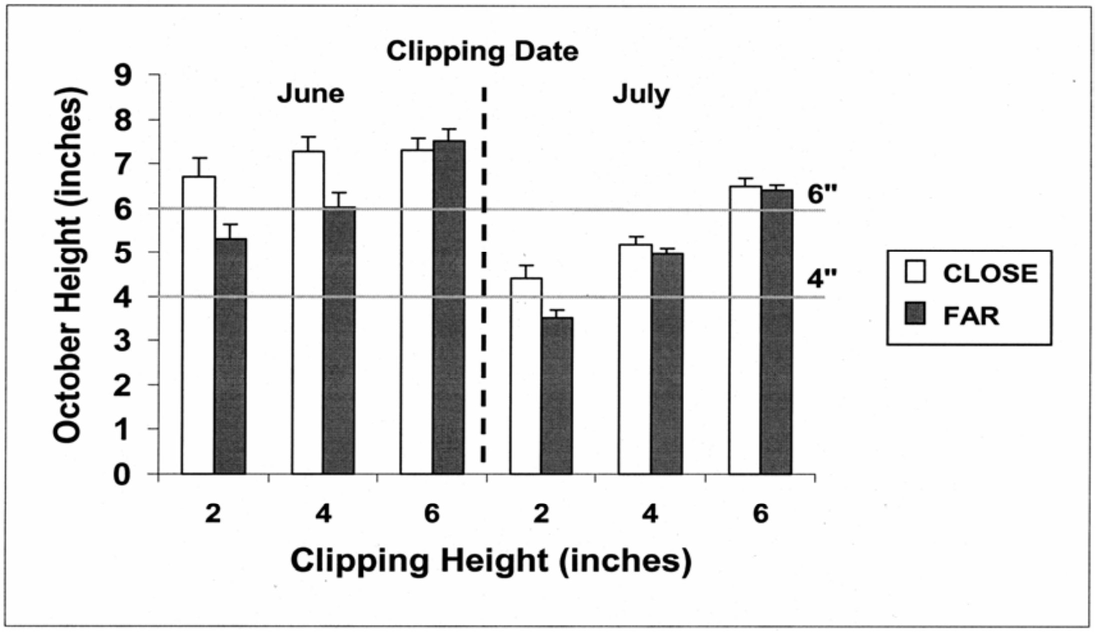
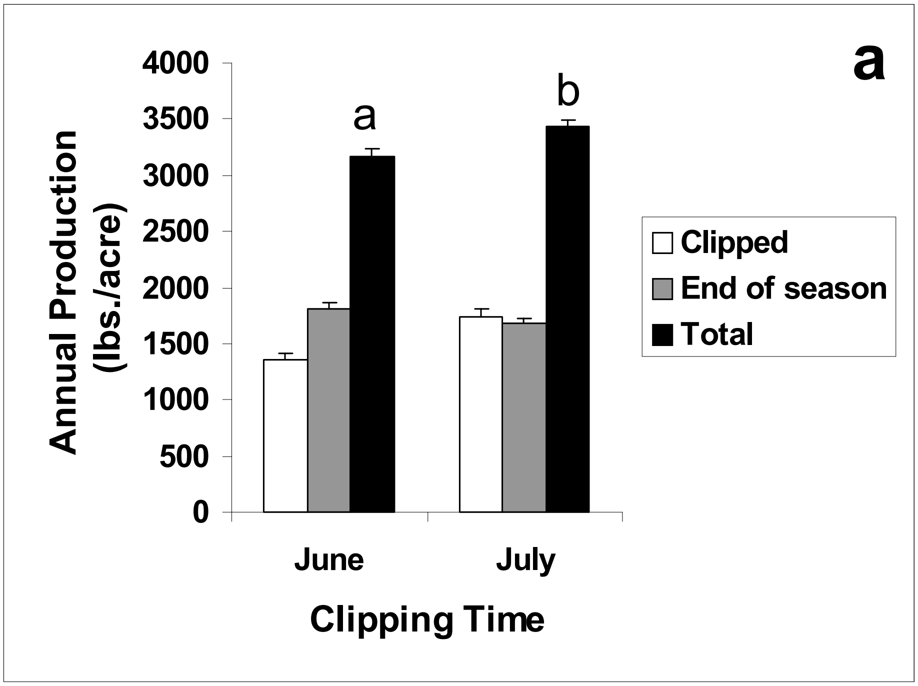


Figure 3. The influence of clipping height, clipping time, and distance from active stream channel on end of growing season (Oct) height for herbaceous riparian plants in plots located along streams in Harney County, Oregon. Lines have been superimposed to indicate 4- and 6-inch stubble height requirements.



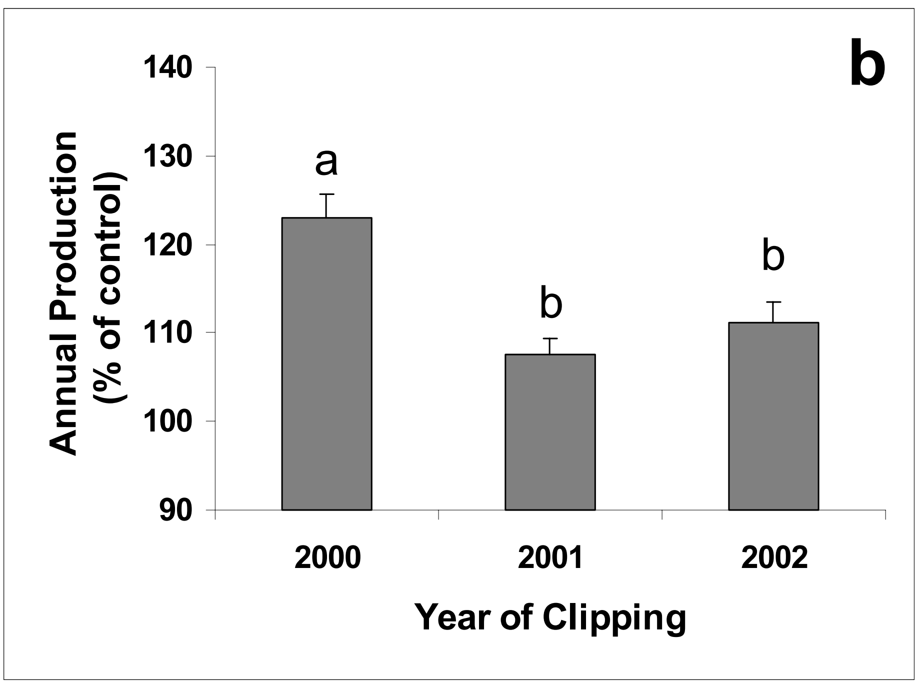


Figure 4. The influence of a) clipping time on annual above ground production, and b) year of clipping, averaged over clipping height and location, on annual above ground production (expressed as a percentage of control plots) for herbaceous riparian plants in plots located along streams in Harney County, Oregon. Bars without a common letter are different at $\alpha = 0.10$. In figure 4a only "total" production was tested in the statistical model; "clipped" bars represent the weight of vegetation harvested at the time of clipping and "end-of-season" bars represent standing crop after clipping plus regrowth.

Discussion

Clipped stubble height and time of clipping were strongly related to end-of-season height regrowth performance. The regrowth response of plants to timing of clipping supported the hypothesis that later clipping (July) produces less regrowth than early clipping (June). This trend would have probably been accentuated with clipping even later in the growing season. In Oregon, Sheeter and Svejcar (1997) reported minimal weight regrowth for herbaceous riparian species clipped to ground level in August, while Gillen et al. (1985) found no regrowth for riparian meadow species grazed after July.

Above ground annual production was relatively insensitive to clipping height, but our data suggest that early summer is a critical time for biomass accumulation, since clipping later in the growing season (July) resulted in greater season-long production (Fig. 4a). Absence of a year effect on annual production suggests that our clipping treatments would be sustainable over time. Production responses to defoliation reported in the literature are not definitive (Pond 1961, Clary 1995, Skinner 1998). Differences in production responses between studies may be associated with species-specific responses with grass-dominated communities responding more positively to defoliation than sedge communities (Pond 1961, Clary 1995). In our study, we observed a compensatory effect of clipping on annual above ground production (i.e., annual production was higher in clipped compared to control plots; Fig. 4b) and the degree of compensatory production was similar across clipping treatments.

From a management perspective, height regrowth response at the clipping heights and times used in this study generally provided sufficient regrowth to meet end-of-growing-season stubble height requirements on federal lands (approximately 4 to 6 inches; Clary 1995). A 4-inch stubble height requirement was met by all but the 2-inch, FAR, July clipping. Conversely, only about 50 percent of the clipping treatments (mainly those clipped in June) met a 6-inch requirement. While end-of-season height was sensitive to clipped stubble height, annual production was not; our data suggest that timing of grazing is more important to maximizing annual production, with late defoliation (July) producing more season-long forage than early (June).

Managers should consider that stubble height is only one of many tools available to gauge management impacts on resource integrity, and that our study of uniform clipping would be difficult to replicate with any type of grazing except very high stocking densities. During dry years and on sites with reduced water availability (e.g., down-cut stream channels), regrowth and production values may respond less positively to defoliation at a given stubble height. Grazed stubble height may interact with season of use, with early-season grazing producing less use of riparian areas at a given stocking rate because of improved palatability of upland forages at this time (Gillen et al. 1985, Clary and Booth 1993). In a larger context, the results of the current study may apply to grazing management of meadow systems that contain riparian-associated plant species but are not directly influenced by stream hydrology. In such cases, our data indicate that grazing during July can maximize herbaceous production compared to grazing earlier in the season. Where feasible, rotational grazing among pastures may be used to provide a balance between residual stubble height and forage production.

Acknowledgements

The authors wish to thank José Zamora and numerous summer employees for assistance in field data collection for this research project. We also thank our cooperators, Don and Kathy Dryer, Mark and Susan Doverspike, and the Burns District of the Bureau of Land Management.

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EFFECT OF MOWING PRIOR TO APPLICATIONS OF PICLORAM AND CLOPYRALID ON RUSSIAN KNAPWEED CONTROL

Michael Carpinelli

Summary

Russian knapweed is a perennial weed that forms dense colonies by adventitious shoots arising from an extensive root system. It infests some of the most productive pasture and hayland of the Great Basin. Fall application of a persistent, soil-active herbicide has been shown to effectively control Russian knapweed. The objective of this study was to investigate if mowing prior to a fall herbicide application improves herbicide efficacy on Russian knapweed. The Brown Brush Monitor™ mows and applies herbicide in a single pass, removing standing dead plants and allowing more herbicide to reach the soil surface. Using the Brown Brush Monitor™, two persistent, soil-active herbicides (picloram and clopyralid) were tested with and without mowing at two sites in southeast Oregon. Treatments were applied in fall 2001, and Russian knapweed control, density, and height were measured in summers 2002 and 2003. Results were inconsistent at Site 1. At Site 2, mowing increased Russian knapweed control by clopyralid in 2002 and by picloram in 2003, and reduced Russian knapweed height and density for both herbicides in 2003. Results from this study suggest that control of Russian knapweed may be improved by mowing prior to fall herbicide application, but that results may be site-specific.

Introduction

Russian knapweed, a perennial forb native to Eurasia, forms dense colonies by adventitious shoots arising from an extensive root system (Whitson 2001). It infests some of the most productive pasture and hayland of the Great Basin. Fall application of a persistent, soil-active herbicide may effectively control Russian knapweed growth the following year (Whitson et al. 1991); however, mowing as an herbicide pretreatment on other perennial weeds has produced inconsistent results (Amor and Harris 1977, Lym and Messersmith 1986, Madsen and Miller 1988, Mislevy et al. 1999, Beck and Sebastian 2000, Bradley and Hagood 2002, Wilson and Michiels 2003). The objective of this study was to investigate if mowing prior to a fall herbicide application improves herbicide efficacy on Russian knapweed. The Brown Brush Monitor™ (Fig. 1) mows and applies herbicide in a single pass, removing standing dead plants and allowing more herbicide to reach the soil surface. Using the Brown Brush Monitor™, mowing alone and two persistent, soil-active herbicides with and without mowing were tested at two sites in southeast Oregon (Fig. 2).

Materials and Methods

Twenty-four plots (6 treatments, 4 replications; plot size = 10 ft by 30 ft, Site 1; 40 ft by 40 ft, Site 2) were arranged in a randomized-complete-block design at each of 2 sites in southeast Oregon. In fall 2001, the following treatments were applied: 4 herbicide treatments (clopyralid [0.38 kg ae ha^{-1}] and picloram [0.5 kg ae ha^{-1}] with and without mowing), a mow-only treatment, and an untreated control. Application rate for each herbicide was the recommended label rate for Russian knapweed. Mow-and-herbicide treatments were made using a Brown Brush Monitor™; herbicide-only treatments were applied using a backpack sprayer (Site 1) or a Spotlyte® sprayer (Site 2). Russian knapweed control, density, and height were measured in summers 2002 and 2003. Control was measured by visually estimating percent reduction of Russian knapweed in treated plots compared to the untreated plots.

Figure 1. The Brown Brush Monitor ™ mows and applies herbicide in a single pass.

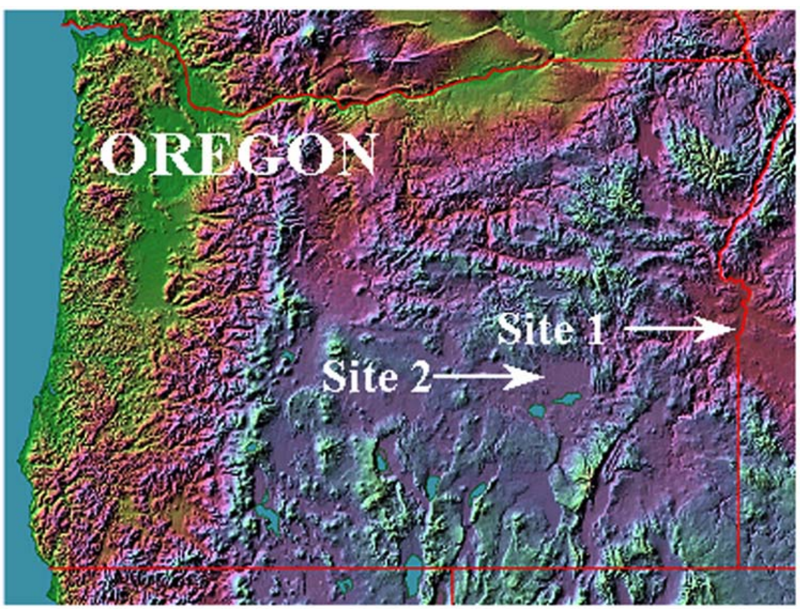

Figure 2. Site 1 was near Adrian, Oregon; Site 2 was near Burns, Oregon.

Results and Discussion

At Site 1, mowing decreased Russian knapweed control by clopyralid in 2002 and had no effect on control by using either herbicide in 2003 (Fig. 3). Russian knapweed density was not influenced by mowing in either year (Fig. 4). In 2002, Russian knapweed height was lower where clopyralid was combined with mowing than where clopyralid was applied alone, but mowing did not affect Russian knapweed height using picloram in either year (Fig. 5).

At Site 2, mowing increased control by clopyralid in 2002 and by picloram in 2003 (Fig. 3). Herbicide effects on Russian knapweed density and height were not influenced by mowing in 2002 (Figs. 4 and 5). In 2003, Russian knapweed height and density were lower where mowing was combined with picloram or clopyralid than where either herbicide was applied alone (Figs. 4 and 5).

While results from Site 1 were inconsistent, results from Site 2 suggest that mowing immediately prior to applying a soil-active herbicide in the fall increases Russian knapweed control and reduces Russian knapweed density and height in subsequent years. At Site 1, herbicide had an overall greater effect, regardless of mowing, than at Site 2. This may be because the Site 1 soil has proportionately more sand and less clay than the Site 2 soil (data not shown), thus facilitating herbicide movement into the rooting zone at Site 1. Perhaps if lower rates of herbicide were used, the effects of mowing on herbicide efficacy would have been more evident at Site 1.

Conclusions

Mowing immediately prior to applying a soil-active herbicide in the fall may increase Russian knapweed control and reduce Russian knapweed density and height in subsequent years, but results may be site-specific.

Future research should investigate how the relationship between mowing and efficacy of fall-applied herbicides is affected by site conditions and by the physiologies and phonologies of different weed species.

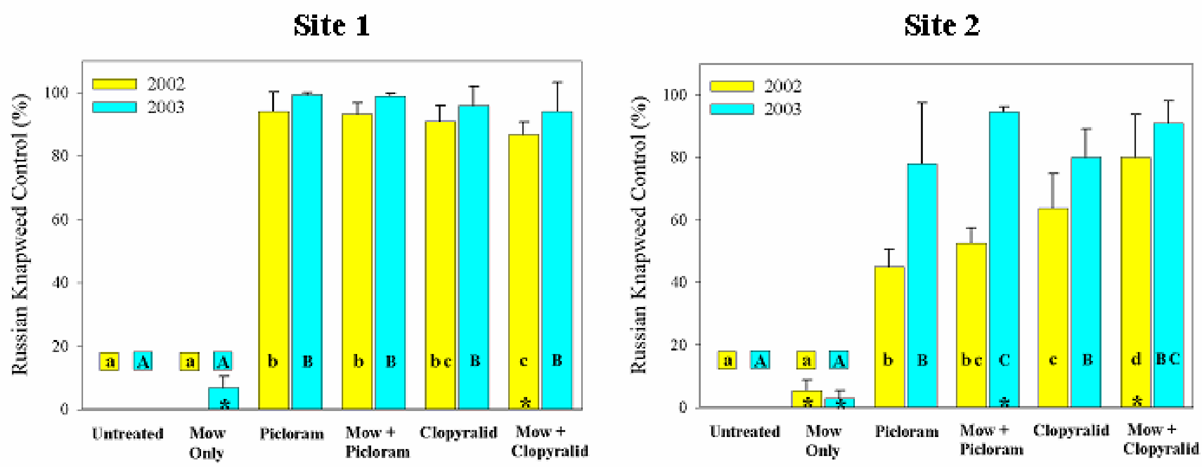

Fig. 3. At Site 1 in 2002, mowing decreased the effect of clopyralid on Russian knapweed control. At Site 2, mowing increased Russian knapweed control with clopyralid in 2002 and with picloram in 2003. By definition, untreated plots have 0% control.

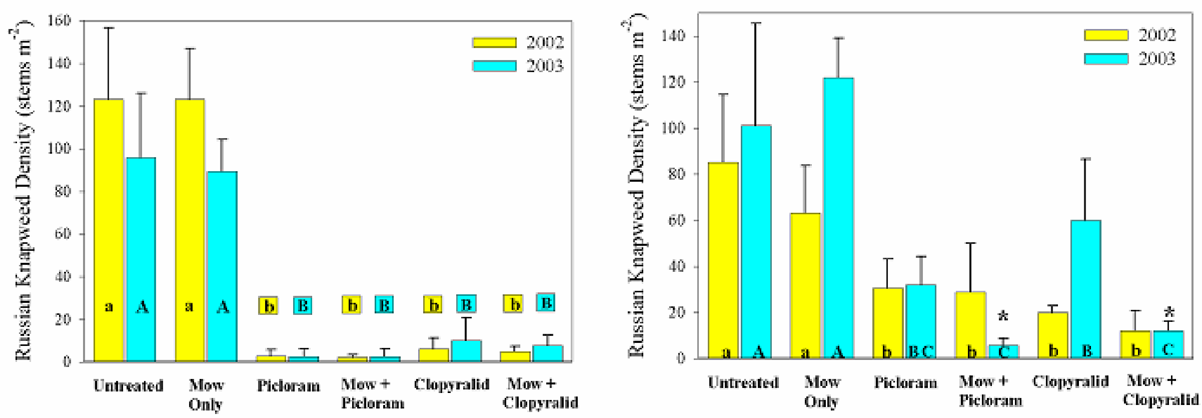

Fig. 4. Mowing had no effect on Russian knapweed density at Site 1; however, mowing increased the effect of picloram and clopyralid on Russian knapweed density at Site 2 in 2003.

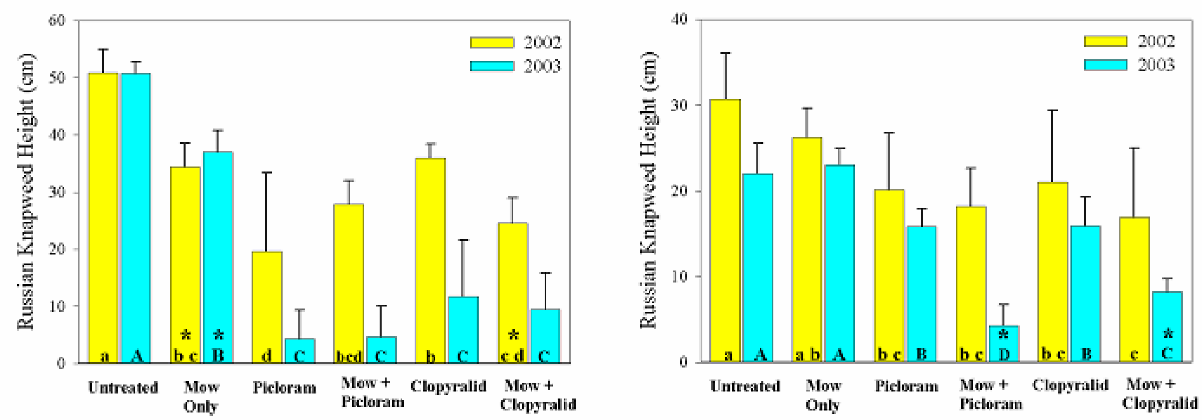

Fig. 5. Mowing increased the effect of clopyralid on Russian knapweed height at Site 1 in 2002, and of both herbicides at Site 2 in 2003.

Figures 3–5. Within-year means sharing the same letter (lower case, 2002; upper case, 2003) are similar (LSD). Asterisk denotes significant mow X herbicide interaction within herbicide and within year. Error bars = SE.

Acknowledgements

We thank Dean Gaiser (Dow AgroSciences), Brett Dunn (Wilbur–Ellis), Bonnie Rasmussen (Harney County Weed Control and Oregon Department of Agriculture), Chuck Rice and Joey Ishida (Malheur Experiment Station), Clare Poulsen (Eastern Oregon Agricultural Experiment Station), Brown Manufacturing Corporation, Robbins Equipment, and Steve Rickman (the Rickman Ranch) for their support and cooperation.

Use of trade names is for the benefit of the reader and does not constitute endorsement by the USDA–ARS or Oregon State University.

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EFFECT OF RUMINAL INCUBATION ON GERMINATION OF PERENNIAL PEPPERWEED SEED

Michael Carpinelli

Summary

Perennial pepperweed invades productive habitats such as flood meadows, riparian areas, and wetlands in most western states, where it displaces desirable forage species. Where chemical or mechanical control is inappropriate, it may be possible to control perennial pepperweed by grazing. However, there is a concern that livestock may ingest seeds that may then be spread to uninfested areas. The goal of this study was to determine the effect of grazing on the viability of perennial pepperweed seeds. Prior to performing a standard germination test, perennial pepperweed seeds were subjected to one of three treatments: incubated in a steer rumen for 48 hours, soaked in water for 48 hours, or kept dry. Ruminal incubation or soaking in water greatly increased germination compared to seeds that were kept dry. These results suggest that if livestock are used to control mature pepperweed, they should be held on weed-free forage for about 1 week prior to being moved to uninfested areas. These results also suggest that spread of pepperweed may be reduced by controlling it in areas where its seeds may eventually be transported by water.

Introduction

Perennial pepperweed (*Lepidium latifolium*) is a perennial weed that spreads from seed, as well as from new stems arising from its creeping root system. It invades productive habitats such as flood meadows, riparian areas, and wetlands in most western states, where it displaces desirable forage species.

It is possible that grazing may be used to control perennial pepperweed. Livestock may be especially effective in areas that are inappropriate for chemical or mechanical control, such as riparian areas. If livestock are used in control efforts, there is a concern that the animals may ingest seeds that may then be spread to uninfested areas. The goal of this study was to determine the effect of grazing on the viability of perennial pepperweed seeds.

Materials and Methods

In fall 2001, perennial pepperweed fruits were collected from the Malheur Wildlife Refuge, about 30 miles south-southeast of Burns, Oregon. Seeds were removed from fruits and were subjected to one of three treatments: 1) incubated in the rumen of a fistulated steer for 48 hours; 2) soaked in water for 48 hours, or; 3) untreated (not incubated or soaked). All treatments were replicated 5 times, and each replicate contained 150 seeds. After incubation or soaking, seeds were rinsed in water and air dried for 3 days. All seeds were then put on sterile, moist media and placed in a germination chamber for 23 consecutive days: the first 14 days at 37° F and the remaining 9 days at 72° F. Seeds were checked daily for germination. It was assumed that seeds that did not germinate within 23 days were not viable. Mean comparisons were made using two-tailed t-tests ($P = 0.05$).

Results and Discussion
Ruminal incubation or soaking in water increased germination 13-fold or 15-fold, respectively, compared to seeds that were kept dry prior to the germination test (Fig. 1).

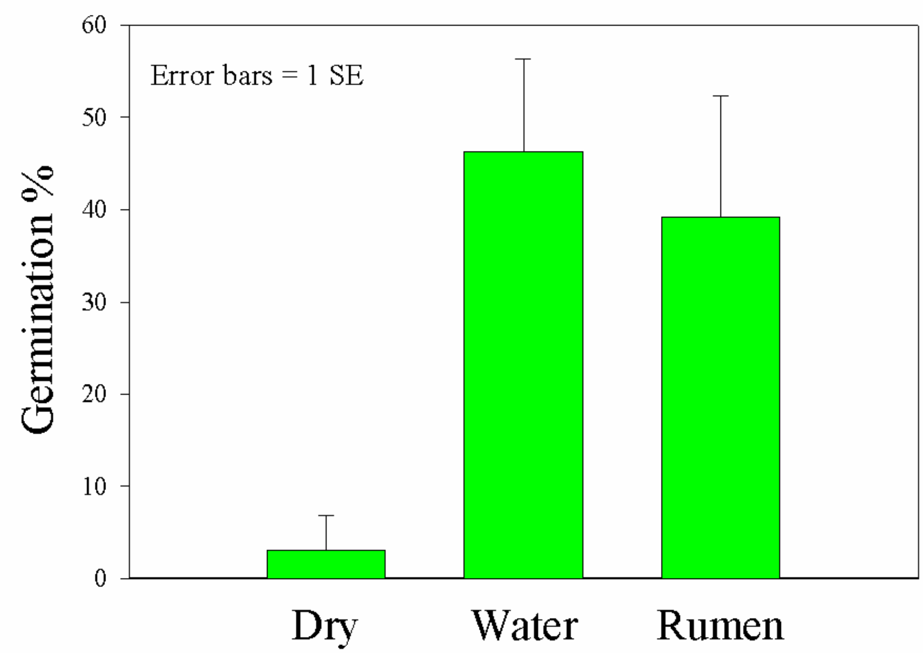

Figure 1. Germination of perennial pepperweed seeds that were soaked in water or ruminally incubated increased more than 10-fold compared to seeds that were kept dry prior to being tested for germination.

Germination did not significantly differ between ruminal incubation and soaking in water. These results suggest that spread of perennial pepperweed may be reduced by controlling it in areas where its seeds may eventually be transported by water (e.g., riparian areas, flood meadows, and irrigation ditches). These results also suggest that if livestock graze perennial pepperweed that has gone to seed, they should be held on weed-free forage for about 1 week prior to being moved to uninfested areas where otherwise, viable perennial pepperweed seeds may be deposited in their dung. Ideally, it may be best to graze perennial pepperweed at the time of flowering to reduce the likelihood that enough growing season or soil moisture will remain to allow grazed plants to flower again and set seed in the same year.

RUSSIAN KNAPWEED GERMINATION AND GRAZING/HERBICIDE TRIALS PRELIMINARY RESULTS

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Summary

Russian knapweed is a noxious weed on rangelands that has proven difficult to control. Germination and grazing/herbicide trials were developed to evaluate germination requirements and infestation response to coordinated grazing and herbicide treatment. Results from the germination trials indicate that germination is limited to areas where wetted soil conditions are maintained for extended periods of time (minimum ~7 days peak germination ~ 25–32 days) and community structural characteristics afford an opportunity for seed coverage by litter or soil. Grazing treatments in 2003 removed 1,400 and 2,600 lbs of knapweed per acre. The crude protein content of the knapweed was 18 percent in June declining to 7 percent by late August. Based on visual observation, goats gained weight and did not show any visible negative effects from the knapweed diet.

Introduction

Russian knapweed (*Centaurea repens*) is a perennial noxious weed that is native to Eurasia (Bottoms and Whitson 1998). It has become particularly troublesome in the semiarid Intermountain West, colonizing saline and non-saline riparian habitats as well as other areas having seasonal shallow water tables.

Russian knapweed reproduces by seed and creeping rootstock and has proven to be a difficult weed to manage on infested rangelands. One author describes Russian knapweed as the most persistent and difficult perennial knapweed to control (Lacey 1989). After initial establishment by seed, infestations of knapweed tend to maintain and spread via adventitious roots rather than through the continued establishment of new seedlings (Watson 1980). Chemical control of established infestations typically requires re-treatment within 3–5 years to maintain adequate control (Bottoms and Whitson 1998). Picloram, clopyralid, and imazapic are three chemicals that show promise for Russian knapweed control. However, rootstock control remains illusive. McInnis et al. (2003) reported increased herbicide effectiveness (rootstock control) on hoary cress regrowth following a mechanical mowing treatment. In that case it was observed that hoary cress regrowth was more uniform in structure and development following treatment and was likely weakened by biomass removal improving the effectiveness of herbicide control on rootstock.

The purpose of the germination trial was to determine the response of Russian knapweed seed to light, decreasing water potential and increasing salinity. The objective of the coordinated grazing (goats)/herbicide trial was to determine if treatment combinations would improve rootstock control of Russian knapweed. The field plots are designed to continue through a grass stand establishment phase, which will begin in fall 2004.

Methods

Germination trial

Russian knapweed seed was collected in 2002 from plants growing in riparian and other low landscape positions within the sagebrush steppe of northeastern Oregon. Watson (1980) reported that knapweed seed production was subject to high rates of seed abortion. Field observations made in 2001 and 2002 suggest that viable seed production is sensitive to summer soil moisture. Knapweed populations were field tested to avoid populations dominated with unfilled seed. Collected seed was stored in plastic grain sacks for 3 months before being removed from the seed heads, cleaned, and separated to avoid shriveled seed for germination studies.

All germination experiments (68°F) were set up in completely randomized designs with four replications. Preliminary germination trials indicated that the germination experiments would run 40 days and require a fungicide treatment. Russian knapweed seeds were rinsed in a 5 percent sodium hypochlorite solution, followed by three distilled water rinses prior to the start of each germination trial. The experimental unit consisted of 50 seeds placed on two sheets of filter paper (Whatman No. 1) in a 100- by 15-mm Petri dish. All experiments were designed to contrast germination under light (500 $uEm^{-2}s^{-1}$ spectral light) and dark conditions.

In the first set of experiments seeds were exposed to four levels of osmotic potential (polyethylene glycol concentrations [PEG]): 0, -0.5, -1.0 and -1.5MPa. Osmotic potentials were verified with a Wescor C-51 thermocouple psychrometer. Hardegree and Emmerich (1990) reported that filter paper selectively absorbed water from PEG solution, thus decreasing the effective osmotic potential that the seed would be exposed to on the filter paper surface. Using the correction equations given in this paper, the actual osmotic potentials were determined to be unchanged.

In the second set of experiments seeds were exposed to five levels of increasing salinity. NaCl and $CaCl_2$ were mixed to achieve electrical conductivities of 0, 4, 8, 12 and 16 dSm^{-1} and a sodium absorption ratio of 2. Electrical conductivities were verified with a conductivity meter. The salt solution gradient approximated 0, -0.12, -0.23, -0.35 and -0.47 MPa (Richards 1954).

Germination counts were taken daily for 40 days. Germination was considered to have occurred at radical emergence. All germinated seeds were removed at each count and treatment solutions were renewed as needed.

Differences among treatment effects were tested by analysis of variance. Mean separation was achieved with least significant difference (LSD) comparisons. Simple linear regressions ($R^2 > 0.85$) were performed to predict rates of germination and the initial date of germination. Differences among the initial date of germination and germination rate estimates were determined using analysis of variance with LSD comparisons. All reported results are significant at $P \leq 0.05$ unless otherwise stated.

Grazing/herbicide trials

The grazing/herbicide trial is being conducted on a site near Burns, Oregon. Preliminary results are reported at this time. All reported results are significant at $P \leq 0.05$ unless otherwise stated. The study area lies within a heavy infestation of Russian knapweed that currently occupies several hundred acres. A split plot experimental design (three blocks) was employed using fall herbicide treatments of control, picloram at 1qt/acre, clopyralid at1.33pt/acre, and imazapic at 12oz/acre coordinated with three grazing treatments in the first year. Grazing treatments consist of no grazing, grazing once during the growing season, and grazing twice during the growing season. A second experimental design was duplicated on the site to test the value of extending the grazing treatment over two growing seasons before applying the fall herbicide treatments. Preliminary trials were conducted in 2002 that verified the willingness of the goats to select knapweed as a major component of their diet.

Results

Germination trial

Russian knapweed germination was completely inhibited at all levels of water stress imposed by PEG (data not shown). Germination at 0.0 MPa was greater under continuous dark conditions when contrasted against a continuous light environment (Table 1). Differences in light versus dark germination among knapweed seed occurred 12 days into the experiment. At the end of the germination trial (40 days), Russian knapweed germination under dark conditions was one and a half times greater than under light conditions (62 versus 39 percent).

Table 1. Cumulative knapweed germination in a light versus dark environment at 0.0 MPa.

Day	Dark	Light	LSD (0.05)
	---------- % ----------		
4	0	0	--
8	3.0	1.6	--
12	8.0	3.2	3.0
16	13.4	5.2	3.9
20	23.4	10.4	4.4
24	31.0	13.6	3.7
28	43.0	21.0	3.7
32	55.2	30.4	8.0
36	60.4	35.6	10.1
40	61.4	39.2	8.3

Knapweed germination was greatest between days 25 and 32 of the experiment regardless of the light treatment (Table 2). Approximately 40 percent of all germination occurred during the 8-day period. The rate of knapweed germination during the first 36 days of the experiment was two times greater in a dark environment when compared to a light environment (1.0 versus 0.5 germinations/day). Light and dark treatment did not influence the number of days required before germination was detected. Germination required approximately 1 week of exposure at near saturated conditions and continued for the next 25 days if moisture conditions were maintained before a decline in germination became evident and the experiment was terminated.

Germination of Russian knapweed seed decreased with increased salt concentration. In a dark environment (40-day germination totals), germination in the non-saline control was greater than 8, 12 and 16 dSm^{-1} (62 versus 49, 31 and 23 percent). Germination at 4 dSm^{-1} (57 percent) was intermediate to germination amounts observed in non-saline and 8 dSm^{-1} treatments. These results suggest that Russian knapweed germinates across a wide spectrum of salt concentration, if sufficient moisture is present. Saline soils are defined as having salt concentrations above 4 dSm^{-1} (Miller and Donahue 1990). Cumulative germination after 36 days of the experiment was reduced 10 percent for each treatment increase in dSm^{-1} (germination count = 31.7 - 1.3(dSm^{-1}), R^2 = 0.86). The rate of germination during the first 36 days of the experiment increased 40 percent as salinity was reduced from 16 to 12 dSm^{-1} (0.3 versus 0.5 germinations/day) and 12 to 8 dSm^{-1} (0.5 versus 0.7 germinations/day). The rate of germination increased 20 percent with salinity reductions from 8 to 4 and 4 to 0 dSm^{-1} (0.7 versus 0.8 and 0.8 versus 1.0 germinations/day).

Table 2. Knapweed germination during each 8-day period in light and dark environments.

Day	Dark	Light[1]	Mean[2]
	----------	%	----------
0-8	3.0a	1.7a	3.0d
9-16	10.4a	3.4b	7.5c
17-24	17.4a	8.4b	15.0b
25-32	24.2a	15.0b	18.6a
33-40	6.2a	8.6a	8.1c

[1] Letter differences across treatment columns are different at $P < 0.05$.
[2] Mean period (8-day) comparisons are vertical ($P < 0.05$).

Under continuous light conditions, germination was greatest in the non-saline control (39 percent). Germination at 4 and 8 dSm^{-1} was similar, but 44 percent less than the control. Germination at 12 and 16 dSm^{-1} had the least amount of germination and averaged 84 percent less germination than the control. Cumulative germination after 36 days of the experiment was reduced 8 percent for each treatment increase in dSm^{-1} (germination count = 17.1 - 1.0 [dSm^{-1}], R^2 = 0.79).

Grazing/herbicide trial

Experimental plots were established in spring 2003 within an infestation of Russian knapweed growing on a fine-loamy, mixed, superactive, frigid Vitritorrandic (Calcidic) Haploxeroll. The fenced perimeter of the experiment contains 6 acres.

Pre-treatment conditions
June 2003
First week

Stem density—Stem density was determined from $0.2m^2$ plots. Each treatment cell (36) within the experiment was sampled using two randomly placed plots in the center of the cell (n = 72). Treatment cell differences were not detected within the 2-year grazing experiment. Russian knapweed stem density (m^2) was 44 ±4 (mean ± standard deviation), hoary cress (*C. draba* + *pubescens*) density (m^2) was 83 ± 8. Within the 1-year grazing experiment, treatment cell differences were not detected for Russian knapweed but block 2 did contain more hoary cress stems than blocks 1 and 3. Russian knapweed stem density (m^2) was 53 ± 2. Hoary cress stem densities (m^2) were 90 stems in blocks 1 and 3 compared to 117 stems in block 2 (LSD = 25).

Biomass—Russian knapweed and hoary cress biomass ($0.25m^2$; oven dry) estimates were determined from 20 plots. Weed biomass was 1,430 ± 230 lbs/acre (mean ± 95 percent confidence interval). Russian knapweed and hoary cress comprised 77 and 23 percent of the biomass, respectively.

July Data
First Week

Control biomass—Control plot biomass (20 plots; $0.25m^2$) was 2,500 ± 400 lbs/acre (mean ± 95 percent CI). Russian knapweed and hoary cress comprised 92 and 8 percent of the biomass, respectively. This represented a 1,100-lb increase in the mean biomass estimate compared to the June estimate.

Grazing treatment one—Four hundred doe and kid goats were placed within the experimental plots on June 17 for 5 days. The biomass (20 plots; $0.25m^2$) at the end of the grazing treatment was 1,100 ± 200 lbs/acre (mean ± 95 percent CI). Russian knapweed contributed 99 percent of the biomass within the experimental plots. The grazing treatment achieved 55 percent utilization.

August Data
Fourth week

Control biomass—Control plot biomass (20 plots; $0.25m^2$) was 2,400 ± 300 lbs/acre (mean ± 95 percent CI). Russian knapweed made up 97 percent of the plot biomass. The difference between the July and August biomass estimates do not represent a measurable decline in biomass.

June grazed plots—The experimental plots grazed in June contained 1,700 ± 300 lbs/acre (mean ± 95 percent CI) prior to the August grazing (20 plots; $0.25m^2$). This represents a 600-lb growth increase in mean biomass between the July and August grazing treatments. The biomass contained in the experimental plots was 100 percent Russian knapweed.

August grazed plots—The second grazing treatment placed 400 doe and kid goats on the designated treatment plots for a second grazing period (August 26–28) of 3 days. The biomass (20 plots; $0.25m^2$) at the end of the second grazing treatment was 500 ± 100 lbs/acre with 100 percent of the biomass being Russian knapweed. The second grazing period achieved 70 percent forage utilization.

Discussion

Germination trial

Continuous light has been observed to inhibit germination in a number of species (Bradbeer 1988, Bewley and Black 1994) and is generally associated with species that favor seed burial or shaded environments. Our results suggest a knapweed germination strategy that favors seed burial and/or shaded environments for germination. Results from the moisture tests indicate that seeds require exposure to moisture conditions near field capacity for approximately 7 days for germination to begin and exposure to that environment for 25 to 32 days yielded the highest daily rate of germination. Knapweed germination decreased with exposure to increased salt concentrations. However, for practical purposes, most sites classified as saline would result in only a moderate reduction in germination.

In the sagebrush steppe, knapweed populations are maintained primarily through vegetative reproduction (creeping root system). Seed development is sensitive to summer soil moisture and appears to result in spotty viable seed production. Knapweed seed is suited to germinate in riparian, wet meadow, sodic meadow and meadow environments. In the wettest years germination could expand to alluvial fans and toe slopes where topographic attributes concentrate soil moisture. However, successful knapweed germination is probably limited to areas where wetted soil conditions are maintained for extended periods of time and community structural characteristics afford an opportunity for seed coverage by litter or soil.

Grazing/herbicide trial

The control plots ended the growing season with 2,400 ± 300 lbs/acre of standing biomass. Peak biomass occurred in the control plots in late June. Plots receiving one grazing period ended the growing season with 1,700 ± 300 lbs/acre of standing biomass. The grazing treatment removed approximately 1,400 lbs/acre of biomass in June and growth within the experimental plots during July and August contributed 600 lbs/acre. Forage utilization under this treatment was 55 percent.

Plots receiving two grazing periods ended the growing season with 500 ± 100 lbs/acre of standing biomass. The first grazing period removed 1,400 lbs/acre of biomass in June, re-growth on the plots in July and August contributed 600 lbs/acre (total biomass = 1,700 ± 300 lbs/acre). The second grazing period removed 1,200 lbs/acre from the plots resulting in an end of season biomass of 500 ± 100 lbs/acre. Approximately 2,600 lbs/acre of knapweed and hoary cress biomass was removed by this treatment strategy. Forage utilization under this treatment was 55 percent in the first grazing period and 70 percent in the second grazing period.

The nutrient content of Russian knapweed and hoary cress was relatively high in June but declined with maturity (Table 3). Goats grazed a steady knapweed diet throughout the summer of 2002 and 2003. They were observed to gain weight and did not appear to exhibit any visible toxic effects.

Table 3. Knapweed and hoary cress nutrient content in June and August 2003.

Nutrient	June		August	
	Knapweed	Hoary cress	Knapweed	Hoary cress
	-------------- % --------------		------------ % -------------	
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Crude Protein	18.5	15.3	7.4	7.4
ADF[1]	32.2	22.8	44.4	32.0
NDF[2]	43.4	33.9	63.3	45.8
TDN[3]	58.0	62.0	54.0	58.0

[1]ADF = acid detergent fiber
[2]NDF = neutral detergent fiber
[3]TDN = total digestible nutrients

Herbicide treatments were applied in mid-October 2003 to the 1-year grazing blocks. Herbicide treatments were control, picloram at 1qt/acre, clopyralid at 1.33pt/acre, and imazapic at 12oz/acre. An assessment of knapweed and hoary cress density and biomass will begin in summer 2004. Seeding trials will begin in fall 2004.

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Figures 1 and 2. Forage Production in a Cut Juniper Woodland
(Jon Bates, Tony Svejcar, and Rick Miller, pages 24-31)

Figure 1. Woodland plot before trees were cut in 1991. Bareground and rock in the interspace is 95 percent. Herbaceous plant cover is about 4 percent.

Figure 2. Cut plot in 1993, 2 years after junipers were felled. By 2003, cover of herbaceous plants was 28 percent, and litter cover was 12 percent. Bareground in the interspace in 2003 was 53 percent.