J. Range Manage.
54: 640–647 November 2001

Nutritional dynamics of 7 northern Great Basin grasses

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Abstract

Land, livestock, and wildlife managers need to understand the nutritional dynamics of forages to sustain adequate growth and reproduction of their animals and/or assure equitable payment for forages. Despite a long history of livestock grazing in the northern Great Basin, seasonal and annual nutritional dynamics of many of the region's prominent grasses have not been described. We addressed this issue via monthly sampling of 7 cool-season grasses at 6 sites during 1992, a drier than average year having 86% of mean precipitation, and 1993, when above average precipitation (167% of average) occurred. With high yields predicted in 1993 (1,257 kg ha^{-1}), the period of adequate forage quality [crude protein (CP) ≥ 7.5%] was 83 days. In addition grasses did not respond to 97 mm of July-August rain with renewed growth. During 1992, a growing season beginning with less than average moisture, grasses responded to midsummer (49 mm) and fall (69 mm) rains by maintaining greater than 7.5% CP for 185 days. A diversity of grasses expanded the period of adequate forage quality especially during the lower than average moisture year. Giant wildrye (*Elymus cinereus* Scribn. & Merr.), a deeply rooted grass, supported high quality forage until mid August, but did not respond to late-season moisture. In contrast, shallow rooted grasses like bottlebrush squirreltail *(Sitanion hys - trix* (Nutt.) Smith), Sandberg's bluegrass (*Poa sandbergii* Vasey), and the winter-annual cheatgrass (*Bromus tectorum* L.) responded to summer or fall moisture with herbage ranging from 10 to 16% CP, thereby supplying high quality late-season forage. With most precipitation occurring in the northern Great Basin during colder months, livestock or habitat managers can, with a fair degree of certainty, predict yields from their pastures before turnout. With abundant moisture, managers will see the rapid deterioration of forage quality that occurs when grasses advance through their reproductive stages of phenology and generate a wealth of reproductive stems. The quandary arrives, however, when moisture accumulations are less than optimum. Fewer reproductive tillers develop, and our results show that timely precipitation may elevate desirable nutrient characteristics and expand the duration of adequate livestock/wildlife nutrition in the region. More long-term research is needed to decipher the mechanisms governing growth and development of rangeland grasses and to assess risks of various stocking alternatives when managers face uncertain yield and forage quality issues.

Resumen

Los manejadores de tierras, ganado y fauna silvestre necesitan entender las dinámicas nutricionales de los forrajes para mantener un crecimiento y una reproducción adecuados de sus animales y/o asegurar el pago equitativo de sus forrajes. A pesar del largo historial de apacentamiento de ganado en la Gran Cuenca del norte, las dinámicas nutricionales estacionales y anuales de muchos de los zacates prominentes de la región no se han sido descritas. Nosotros abordamos este problema a través de muestreos mensuales de 7 zacates de estación fría en 6 sitios durante 1992, un año mas seco que el promedio teniendo solo el 86% de la precipitación media, y en 1993 cuando ocurrió una precipitación arriba del promedio (167% de la precipitación media). Con rendimientos altos predichos en 1993 (1,257 kg ha^{-1}), el período en el que el forraje tuvo una calidad adecuada [proteína cruda (PC) ≥ 7.5%] fue de 83 días. Además, los zacates no respondieron con crecimiento nuevo a los 97 mm de lluvia que ocurrieron entre Julio y Agosto. Durante 1992, una estación de crecimiento que inicio con menos humedad del promedio, los zacates respondieron a las lluvias de mediados de verano (49 mm) y otoño (69 mm) al mantener el contenido de proteína cruda arriba del 7.5% durante 185 días. Una diversidad de zacates expandió el período de calidad adecuada del forraje, especialmente durante el año de precipitación abajo del promedio. "Giant wildrye" (*Elymus cinereus* Scribn. & Merr.), un zacate con raíz profunda, mantuvo una calidad alta hasta mediados de Agosto, pero no respondió a la humedad de fines de estación. En contraste, zacates de raíz poco profunda como "Bottlebrush squirreltail (*Sitanion hystrix* (Nutt.) Smith), "Sandberg's bluegrass" (*Poa sandhergii* Vasey) y el anual invernal "Cheatgrass" (*Bromus tectorum* L.) respondieron a la humedad de verano y otoño con un contenido de proteína cruda en el forraje que varió 10 a 16%, por lo tanto suministraron un forraje de alta calidad a fines de la estación de crecimiento. En la región de las Gran Cuenca del Norte, en donde la mayor precipitación ocurre durante los meses fríos, los manejadores de ganado o de hábitat pueden, con un grado regular de certidumbre, predecir los rendimientos de sus potreros antes de que este ocurra Con precipitación abundante, los manejadores verán el rápido deterioro de la calidad del forraje, la cual ocurre cuando los zacates avanzan a través de sus etapas fenológicas reproductivas y generan una abundancia de tallos reproductivos. Sin embargo, el dilema llega cuando las acumulaciones de humedad son menores al óptimo. Pocos tallos reproductivos se desarrollan y nuestros resultados muestran que la precipitación oportuna puede elevar las características nutritivas deseables y extender la duración de una nutrición adecuada para el ganado y fauna silvestre de la región. Se requiere una investigación de más larga duración para descifrar los mecanismos que gobiernan el crec

[1]Eastern Oregon Agricultural Research Center, including the Burns and Union Stations, is jointly operated by the USDA-Agricultural Research Service and the Oregon Agr. Exp. Sta. of Oregon State University.

Technical Paper No. 11737 Oregon Agr. Exp. Sta.
Manuscript accepted 21 Dec. 00.

imiento y desarrollo de los zacates de pastizal y evaluar los riesgos de varias alternativas de carga animal cuando los manejadores encaran problemas de incertidumbre respecto a los rendimientos y calidad del forraje.

Key Words: crude protein, neutral detergent fiber, in vitro organic matter disappearance, *Poa sandbergii, Bromus tectorum, Sitanion hystrix, Agropyron spicatum, Festuca idahoensis, Stipa thurberiana, Elymus cinereus*

Stockmen and wildlife managers need to understand nutritional dynamics of forages on rangelands to sustain adequate growth and reproduction of their animals. In a similar vein, those marketing pasture should also be aware of nutritional characteristics of their forages to assure reception of equitable payment. Despite a long history of livestock grazing in the northern Great Basin, there have been few concerted efforts to quantify seasonal and annual nutritional dynamics of many of the region's most prominent rangeland grasses (Murray et al. 1978).

The northern Great Basin experiences an arid Mediterranean climate with about 80% of the annual precipitation occurring in the fall, winter, and spring months when low temperatures preclude plant development. Rangeland grasses typically initiate growth with warming temperatures in March or April, and herbage accumulations cease with depletion of soil moisture in mid- to late July (Sneva 1982, Ganskopp 1988). Wallace et al. (1961) described in vitro cellulose digestibility of 6 grasses from 30 May to 5 September, with values ranging from a high of 76% to a low of 37% late in the season. Raleigh (1970) and McInnis and Vavra (1987) monitored nutritional indices of grasses from late April to early September and noted that forage quality began deteriorating even before stems started elongating in the spring. Quality continues to decline until early August when forages mature and dry (Raleigh 1970, Murray et al. 1978). Murray et al. (1978) also quantified mineral content for several of the region's grasses. Rates of gain for livestock reflect nutritional dynamics of the region's forages with mature cows gaining up to 1.86 kg day^{-1} early in the growing season and losing 0.4 kg day^{-1} by mid- to late August (Raleigh and Wallace 1965, Turner and DelCurto 1991). Within the same period, calf gains may range from 0.7 to as little as 0.1 kg day^{-1} (Turner and DelCurto 1991).

Our objective was to characterize seasonal and annual nutritional dynamics of 7 of the region's most prominent grasses. This was accomplished via monthly sampling at 6 sites during 1992, a drier than average year, and 1993 when above average precipitation occurred.

Materials and Methods

After extensive reconnaissance in the fall of 1991, six study locations within the vicinity of Burns, Ore. were selected with each supporting a broad array of forages (Table 1). Climatological data reported here were acquired at the Northern Great Basin Experimental Range with the recording unit identified as the Squaw Butte Experiment Station in N.O.A.A. records (N.O.A.A. 1991 through 1994). The second site listed in Table 1 provides coordinates for the weather station. Among the 6 locations, mean soil depth was 69 cm (se = 5.1), and elevation ranged from 1,375 to 1,472 m ($\bar{x}$ = 1,429). On an east/west line the sites spanned 118 km, while the north/south extreme encompassed 75 km.

The shrub component at each site was dominated by Wyoming big sagebrush (*Artemisia tridentata* subsp. *wyomingensis* Beetle) with occasional occurrences (<10% relative cover) of mountain big sagebrush (*Artemisia tridentata* subsp. *vaseyana* (Rydb.) Beetle). Dominant perennial grasses were either bluebunch wheatgrass (*Agropyron spicatum* (Pursh)Scribn. & Smith) or Idaho fescue (*Festuca idahoensis* Elmer). Subordinate grasses included Sandberg's bluegrass (*Poa sandbergii* Vasey), bottlebrush squirreltail (*Sitanion hystrix* (Nutt.) Smith), Thurber's needlegrass (*Stipa thurberiana* Piper), giant wildrye (*Elymus cinereus* Scribn. & Merr.), prairie Junegrass (*Koeleria cristata* Pers.), and in disturbed areas, the introduced annual cheatgrass (*Bromus tectorum* L.). All of these grasses are common in the sagebrush steppe, and with the exception of prairie Junegrass, one or another may dominate the herbaceous layer depending on site specific conditions and environmental factors (Daubenmire 1970, Hironaka et al. 1983).

Seven grasses were evaluated in this study. These included: Sandberg's bluegrass, cheatgrass, bottlebrush squirreltail, bluebunch wheatgrass, Idaho fescue, Thurber's needlegrass, and giant wildrye. In 1992 and 1993, we visited all 6 locations within a 3-day interval at the end of each month. Months sampled included April-November in both years.

Once a month at each site samples were harvested from at least 6 plants per species by clipping to a 2.5-cm stubble and compositing materials by species. Greater numbers of plants were used for small stature grasses like Sandberg's bluegrass. Plants at each site were sampled as encountered along a pace transect until adequate amounts of material were obtained. Each site experienced light (< 40% utilization) summer-fall grazing by cattle, but only ungrazed plants were included in our collections. Samples gathered prior to the beginning of spring growth consisted of leaves and culms generated in the previous growing season. After growth initiated in the spring, crowns of caespitose grasses were lightly crushed and the brittle and broken old-growth brushed aside before samples were collected. Samples were stored in paper bags in the field and transported to Eastern Oregon Agricultural Research Center headquarters where they were oven-dried at 60° C for 48 hours, ground to pass a 1-mm screen, and stored in plastic bags at room temperature for subsequent chemical analyses. Samples were analyzed for crude protein content (CP = Kjeldahl nitrogen × 6.25; AOAC 1984), neutral detergent fiber (NDF; Robertson and Van Soest 1981), and percent in vitro organic matter disappearance (IVOMD; AOAC 1990).

Table 1. Coordinates, elevation, and soils classification of sites where 7 species of grasses were harvested for assays of forage quality in southeastern Oregon during 1992 and 1993.

Coordinates	Elevation (m)	Soil
120° 03' 29"W 43° 34' 54"N	1463	fine-loamy, mixed, frigid Aridic Argixerolls
119° 42' 30"W 43° 29' 37"N	1452	fine-loamy, mixed, frigid Aridic Argixerolls
119° 19' 08"W 43° 28' 59"N	1472	loamy-skeletal, mixed frigid Lithic Argixerolls
119° 00' 21"W 43° 26' 45"N	1375	loamy-skeletal, mixed, frigid Aridic Haploxerolls
118° 39' 01"W 43° 59' 05"N	1402	clayey-skeletal, montmorillonitic, frigid Lithic Xeric Haplargids
118° 35' 55"W 43° 39' 40"N	1411	loamy-skeletal, mixed, frigid Aridic Haploxerolls

Experimental design was a randomized complete block with 6 replications (sites) and 3 factors (years (n = 2), months (n = 8), and forages (n = 7)). Initial analyses employed a split-split-plot analysis of variance with species as whole-plots, years as subplots, and months as sub-sub-plots (Petersen 1985). The replication × species error term (30 df) was used to test for species effects. The replication × year × species error term (35 df) tested the main effect of year and year × species interaction, and the species × year × replication × month error term (490 df) tested for month main effects and the month × forage, species × month, and species × year × month interactions. Year effects and all interactions involving year effects were found to be highly significant ($P < 0.001$), so data were sorted by year, and years were analyzed separately using a split-plot analysis of variance with species serving as whole plots. Mean separations within a forage between adjacent months were obtained with Fisher's protected LSD (Fisher 1966) with statistical significance accepted at $P \leq 0.05$. Associations among CP, IVOMD, and NDF variables pooled across replications, years, months, and forages were quantified via correlation analyses (n= 672) .

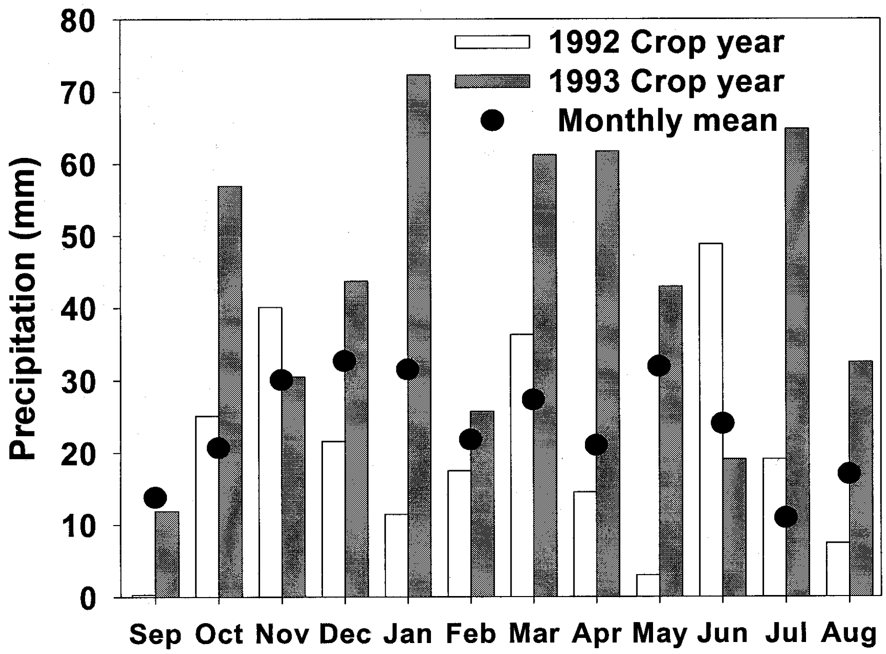

Fig. 1. Monthly precipitation for the 1992 (September 1991–June 1992) and 1993 (September 1992–June 1993) crop-years, plus the months of July and August in 1992 and 1993, and mean monthly accumulations (n = 41) at the Northern Great Basin Experimental Range near Burns, Ore.

Results

Weather patterns

Precipitation accumulations compiled on a calendar year basis at the Northern Great Basin Experimental Range were 106 and 140% of the long-term average ($\bar{x}$ = 283 mm, n = 41) for 1992 and 1993, respectively (N.O.A.A. 1992–1993). Sneva (1982), however, established that annual forage yields in the region were most closely correlated with precipitation accumulated on a crop year or September through June basis. With that logic, accumulations for the 1992 and 1993 growing seasons at the Northern Great Basin Experimental Range were 86 and 167% of the crop year average (255 mm), respectively (Fig. 1). Mean April–July temperatures were 2.5° C warmer than average ($\bar{x}$ = 12.4° C) in 1992 and 1.6° cooler than average in 1993. A model for predicting annual herbage yields in the region furnished production estimates of 542 kg ha^{-1} for 1992 and 1,257 kg ha^{-1} for 1993 (Sneva 1982).

Forage quality assessments

All 3 indices of forage quality (CP, IVOMD, and NDF), were significantly affected by year and interactions involving years ($P < 0.001$). Overall, year main effects averaged about 12% of the total variation in the split-split-plot analyses of variance. When years were removed from the models and analyzed separately, main effects of species and months, and the month × species interactions were again all highly significant ($P < 0.001$). When averaged among all 3 indices of forage quality and both years, the main effect of month accounted for about 80% of the total variation, and species of forage contributed approximately 10%. As a result, data for each species are presented at a monthly resolution for each year.

Crude protein

The highest CP content (25%) was obtained with giant wildrye during the spring of 1993 (Fig. 2), and the lowest level (2%) occurred with cheatgrass in late-September of 1993. In both years, all of the grasses exhibited their most rapid declines in CP concentrations from late-April to late-June. With the exception of giant wildrye, CP content generally approached minimum levels by late July with no significant ($P > 0.05$) declines thereafter. In giant wildrye, crude protein levels were sustained until late September. The greatest amount of variation in CP content was exhibited by Sandberg's bluegrass, and the least was displayed by bluebunch wheatgrass. The seasonal range in CP content averaged from 10 to 17 percentage points in 1992 and 1993, respectively. Giant wildrye exhibited the greatest seasonal variation in both years and the lowest seasonal variation occurred in Idaho fescue in 1992 and Thurber's needlegrass in 1993.

Two patterns clearly illustrate the significant ($P < 0.001$) year effects and interactions that occurred with our initial analyses of variance (Fig. 2). First, initial CP concentrations were consistently higher in 1993 than in 1992 but subsequently declined to lower levels in 1993 than in 1992. Second, the CP declines in 1993 appeared curvilinear and could probably be modeled by second order response functions, while CP levels in 1992 generally displayed 3 peaks that would be difficult to describe numerically. These 1992 fluctuations were induced by summer and fall precipitation events. In late-July 1992, bottlebrush squirreltail responded significantly ($P < 0.05$) to 49 mm of rain in the preceding month with an increase of 4.9 percentage units in CP content. The other 6 grasses displayed similar patterns with slight elevations in CP, but their increases were not significant ($P > 0.05$).

Fifty-seven millimeters of rain in October 1992 induced growth and nutrient uptake and significantly elevated late-October CP in Sandberg's bluegrass,

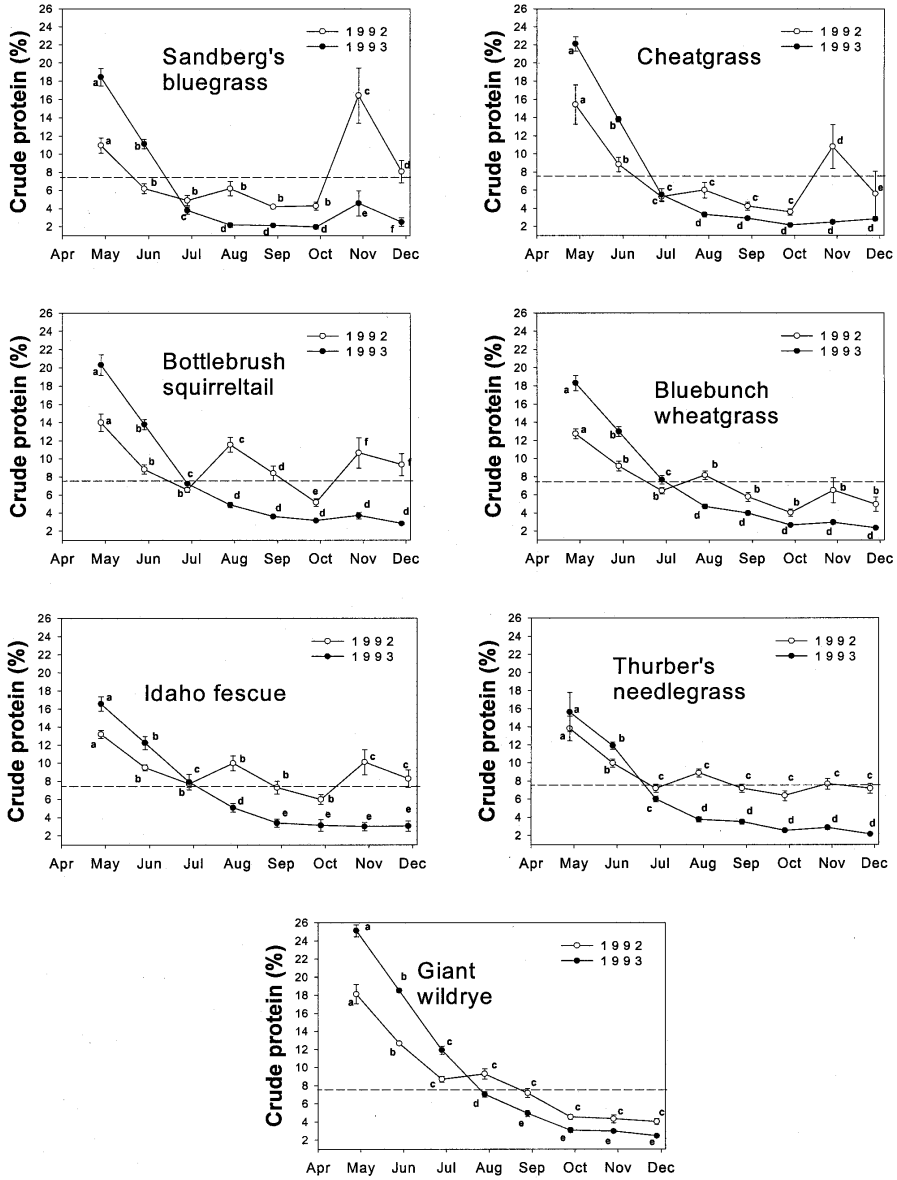

Fig. 2. Percent crude protein (±SE) of 7 grasses sampled over 8 monthly intervals at 6 different sites in the sagebrush steppe near Burns, Ore. during 1992 and 1993. Dashed horizontal lines (- - - - -) depict a 7.5% CP level. Adjacent monthly means within a year sharing a common letter are not significantly different (P > 0.05). LSD (P = 0.05) = 2.8 for 1992 and 1.5 for 1993.

cheatgrass, bottlebrush squirreltail, and Idaho fescue. Bluebunch wheatgrass, Thurber's needlegrass, and giant wildrye showed no significant responses. Oddly, the second highest monthly accumulation of rain (65 mm) that occurred during the study (July 1993) failed to elicit a significant ($P > 0.05$) response from any of the grasses. Precipitation accumulations for September, October and November of 1993 were 1, 14, and 0 mm, respectively, and no fall green-up occurred among any of the grasses.

In vitro organic matter disappearance

The highest IVOMD (81.8%) occurred in cheatgrass in late April, 1993, and the lowest (28.7%) was obtained from bluebunch wheatgrass in late October, 1993 (Fig. 3). Variability between years and corresponding months was greatest for Sandberg's bluegrass and lowest for giant wildrye (Fig. 3). Across years, months, and species, IVOMD was positively correlated with CP content ($r = 0.91$, $P < 0.001$). Annual and seasonal patterns visually approximated those obtained with CP concentrations. With the exception of Thurber's needlegrass, IVOMD values began at lower levels in 1992 and ended the year at higher levels in 1992 than in 1993. As with CP, patterns of seasonal decline were curvilinear in 1993 and, with the exception of Sandberg's bluegrass, IVOMD decreased through late October.

The greatest range of seasonal change in IVOMD occurred with cheatgrass (1992) and giant wildrye (1993), while the smallest range of seasonal change was exhibited by Idaho fescue in 1992 and Thurber's needlegrass in 1993. Within forages and between years and months, variation in IVOMD was highest for Sandberg's bluegrass and lowest for giant wildrye.

Five of the 7 grasses (Thurber's needlegrass and giant wildrye excluded) responded to above average October precipitation (57 mm) in 1992 by significantly ($P < 0.05$) increasing late-October IVOMD (Fig. 1). However, the 65 mm of rain that occurred in July of 1993 did not induce changes in any of the grasses.

Neutral detergent fiber

During both years, grass NDF increased in a manner typical of maturing forages (Fig. 4) in a Mediterranean environment. Among grasses, seasonal increase in NDF averaged about 18% and 27 percentage points for 1992 and 1993, respectively. The lowest NDF (38.5%) occurred with cheatgrass in late April 1993, and the highest fiber level (80.9%) was found with giant wildrye in late November 1992.

Within forages, variability between years and corresponding months was highest with cheatgrass and lowest with bluebunch wheatgrass and Thurber's needlegrass. All the grasses started the growing season with lower NDF levels in 1993 than in 1992; and with the exception of bluebunch wheatgrass and giant wildrye, end of the year NDF values were higher in 1993 than in 1992. October precipitation in 1992 induced green-up and a significant decrease in NDF for Sandberg's bluegrass, cheatgrass, and squirreltail. The July rainfall of 1993 had no effect on NDF of forages. Because fiber content of grasses increased as foliage matured and our other indices of forage quality (CP and IVOMD) declined with maturity, NDF dynamics were negatively correlated with CP ($r = –0.80$) and IVOMD ($r = –0.85$).

Discussion

Although crop year precipitation (86% of mean) contributing to forage growth in 1992 could not be defined as a drought

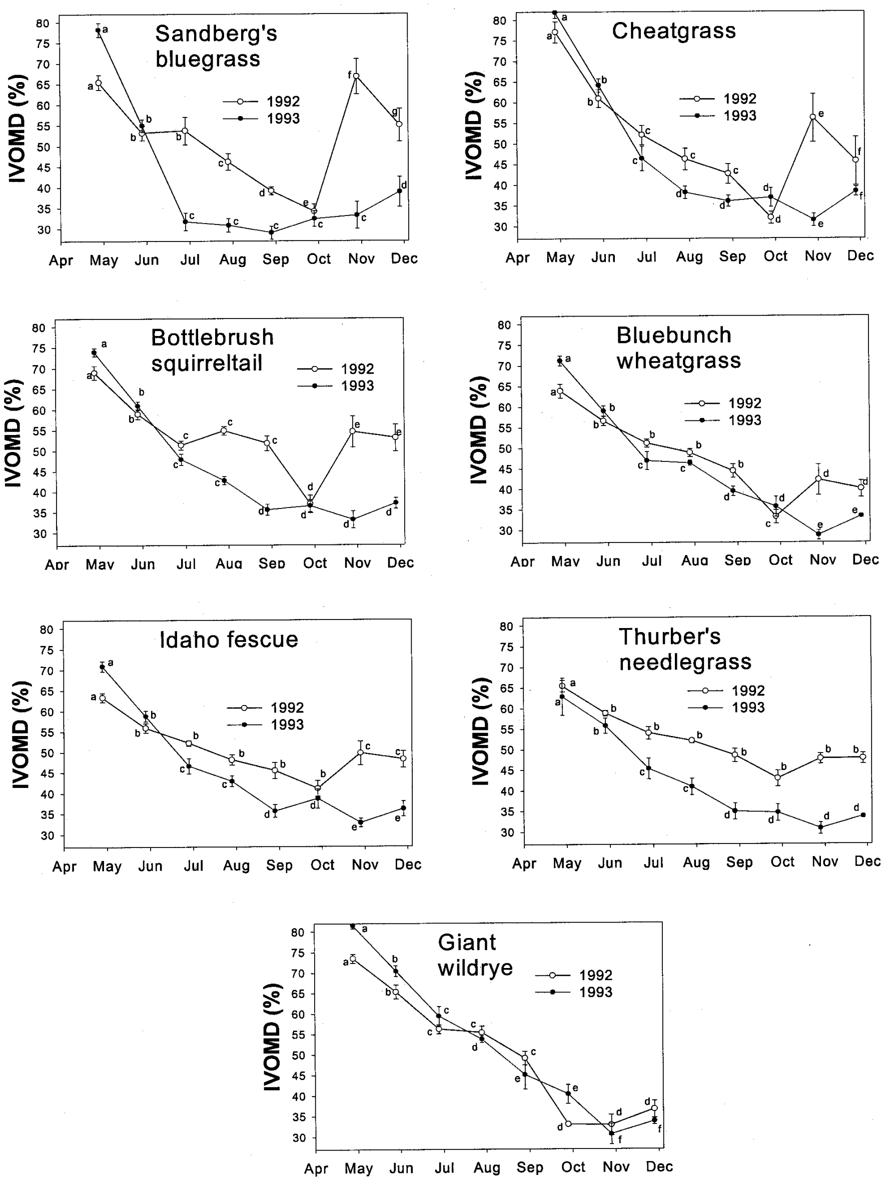

Fig. 3. Percent in vitro organic matter disappearance (±SE) of 7 grasses sampled over 8 monthly intervals at 6 different sites in the sagebrush steppe near Burns, Ore. during 1992 and 1993. Adjacent means within a year sharing a common letter are not significantly different (P > 0.05). LSD (P = 0.05) = 6.4 for 1992 and 5.4 for 1993.

(Society for Range Management 1974), perceptions among regional land and livestock managers were that forages and stock water were in short supply. In contrast, water and forage supplies were viewed as more than adequate in spring 1993. The disparity in herbage yields between these 2 years, estimated with Sneva's (1982) forage yield model (1992 = 542 kg ha^{-1} and 1993 = 1,257 kg ha^{-1}) suggests those perceptions were justified.

From a nutritional standpoint, our forage quality assays imply those views might be reversed. Crude protein is only 1 of several important forage characteristics for rangeland herbivores. Among forages, however, CP levels are well correlated with many desirable plant components like digestibility, vitamins, calcium, and phosphorus. These all decline to deficient levels at about the same time, and CP serves as a reliable measure of overall nutritional value (Sullivan 1962). Also, we adopted a 7.5% CP level as an adequate forage quality threshold because it falls within the range of values suggested for maintenance of many wild and domestic herbivores (French et al. 1955, Thorne et al. 1976, Schwartz et al. 1977, NRC 1978, 1981, 1984).

The greatest disparity between the 2 years was the length of time when adequate CP levels were available. During our sampling period (approximately 217 days each year) one or more of the forages supplied CP levels above 7.5% for about 185 days in 1992 and only 83 days in 1993 (Fig. 5). In other words during our sampling period, available forage was CP deficient for about 32 days (mid September-early October) in 1992 and 134 days (late July-November) in 1993. Large herbivores typically harvest diets of higher quality than hand-compounded rations or whole-plant samples (Kiesling et al. 1969, McInnis and Vavra 1987, Cruz and Ganskopp 1998), so adequate CP concentrations probably extend for longer periods of time in applied situations.

Maintenance of a diversity of forages within pastures is important, especially when conditions are less than optimum. In 1992, Idaho fescue furnished herbage of at least 7.5% CP for a total of 177 days while giant wildrye ranked second and yielded 172 contiguous days of herbage above 7.5% CP (Fig. 2). Bottlebrush squirreltail furnished adequate forage for a few days in early September, when Idaho fescue was deficient, and Sandberg's bluegrass responded to October precipitation and elevated fall forage quality more quickly than Idaho fescue (Fig. 2).

A diversity of forages did not offer the same advantages in 1993 that occurred in 1992, however. With abundant spring soil moisture in 1993, all of the grasses quickly advanced through maturity, and all herbage was deficient in CP by late July. The 64 mm of precipitation that occurred in July 1993 failed to sustain the green feed period or cause new tillers to develop among any of the grasses. In 1993, giant wildrye displayed the longest period (83 days) of adequate CP followed by Idaho fescue at 69 days.

Murray et al. (1978) monitored forage quality of 4 grasses included in our study (cheatgrass, giant wildrye, Sandberg's bluegrass, and bottlebrush squirreltail) through 7 growing seasons in southern Idaho. Their figures generally approximate the same second order response functions depicted by our 1993 data. They did not present specific annual patterns of precipitation within their illustrations, however, so we cannot relate seasonal variability in forage quality with annual precipitation dynamics (Murray et al. 1978).

We speculate the different response between years to summer precipitation is related to the growth and development patterns of cool-season, caespitose grass-

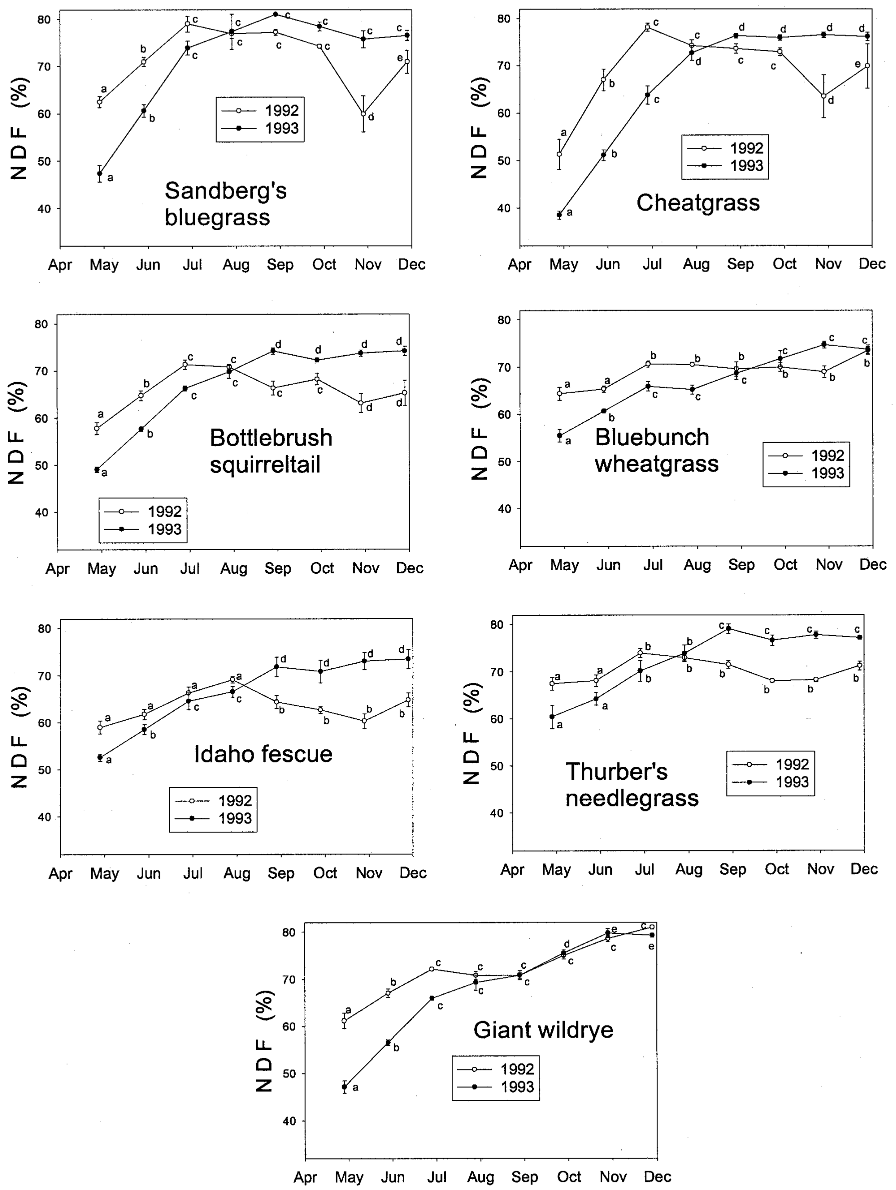

Fig. 4. Percent neutral detergent fiber (±SE) of 7 grasses sampled over 8 monthly intervals at 6 different sites in the sagebrush steppe near Burns, Ore. during 1992 and 1993. Adjacent means within a year sharing a common letter are not significantly different (P > 0.05). LSD (P = 0.05) = 4.7 for 1992 and 3.9 for 1993.

es. Typically, tiller recruitment occurs in the fall. Individual tillers overwinter, extend leaves, differentiate, mature, and die during the subsequent growing season (Richards and Caldwell 1985, Mueller and Richards 1986, Olson and Richards 1988, Miller and Rose 1992). When spring moisture is abundant, nearly all tillers advance through maturity, and any new growth after mid-summer requires activation of new axillary buds. Some cool-season grasses actually enter summer dormancy and will not respond to midsummer moisture (Keller 1959, Hyder 1961). Field notes on our data sheets indicate a wealth of reproductive stems were generated in the 1993 growing season, and these probably contributed greatly to the rapid declines in CP and IVOMD and increases in NDF among all the grasses. Stems are typically lower in protein and digestibility than their accompanying leaves (Hacker and Minson 1981, Buxton and Marten 1989, Bidlack et al. 1999)

In 1992, spring soil moisture was not adequate to carry tillers to maturity. In response, adolescent tillers most likely became quiescent and then responded to June precipitation with renewed growth and a belated effort to reach maturity (Hyder 1972). Because nearly all tillers reached maturity by mid-summer in 1993, there were few if any live stems that could capitalize on July precipitation.

Of the 4 grasses (Sandberg's bluegrass, cheatgrass, bottlebrush squirreltail, and Idaho fescue) that had significant ($P < 0.05$) increases in CP and IVOMD with 1992 fall precipitation, Sandberg's bluegrass was the highest with 16.4% CP (Fig. 2) and 67% IVOMD. Also, Sandberg's bluegrass was the only grass that displayed a significant ($P < 0.05$) increase in CP during October 1993. Although Sandberg's bluegrass is small in stature, it is the first grass in the region to green in the spring. Sandberg's bluegrass supports a dense carpet of shallow fibrous roots, and it can readily respond to small amounts of mid-summer or fall precipitation (Sneva 1982). Though it is not known as a major contributor to the standing crop, its growth habits combine to make it a desirable species that can enhance diet quality. Consequently, several rangeland herbivores seek it out early in the growing season (Vavra and Sneva 1978).

The CP and NDF dynamics of cheatgrass, the only annual included in our study, closely mimicked those of Sandberg's bluegrass (Figs. 2, 3, and 4). Like Sandberg's bluegrass, cheatgrass is a source of early spring forage (Cook and Harris 1952) and, because it functions as a winter annual with fall germination (Stewart and Hull 1949), it can contribute immature, high quality herbage late in the grazing season. Cheatgrass is famous for its extreme year to year variation in yield (Hull 1949, Murray and Klemmedson 1968), and it also provided the fewest days of adequate CP of any of the grasses in both years of our study (74 days in 1992 and 36 days in 1993).

Bottlebrush squirreltail was distinguished by its marked responses to summer and fall precipitation (Fig. 2). Hyder (1972) suggested bottlebrush squirreltail frequently supports culmless vegetative tillers that may be able to respond and differentiate with favorable conditions through the summer. In many years we have observed bottlebrush squirreltail flowering throughout the growing season. It is an early succession and increaser species in the region (Daubenmire 1970), and its opportunistic growth pattern may allow it to expedite reproduction and colonization of disturbed sites.

A distinctive feature of giant wildrye was its minimal response, based on our indices, to summer or fall precipitation (Figs. 2, 3, and 4). Of the grasses sampled,

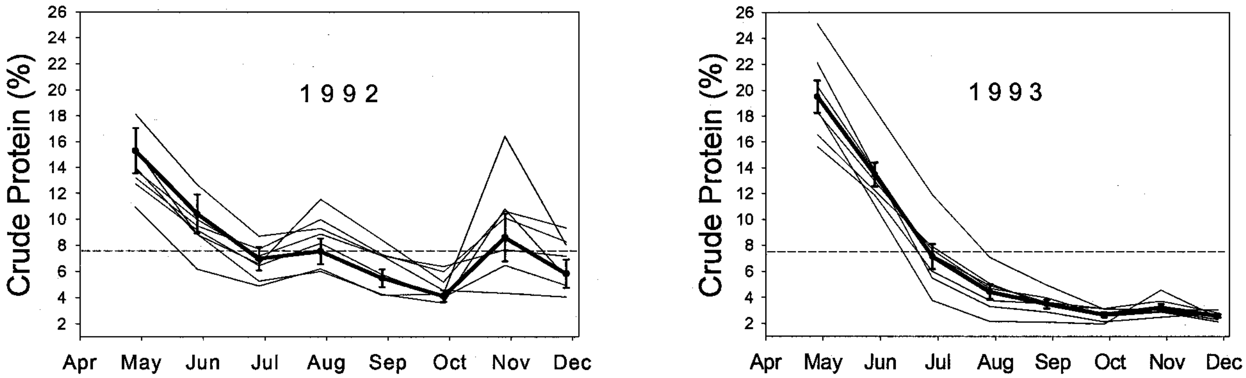

Fig. 5. Percent crude protein of 7 grasses (light lines) and the mean and SE (dark heavy line) across grasses sampled over 8 monthly intervals at 6 different sites in the sagebrush steppe near Burns, Ore. in 1992 and 1993. Dashed horizontal lines (- - - - -) depict a 7.5% CP level.

giant wildrye was the largest in stature, most deeply rooted, and last to emerge in spring. We suspect these growth habits combine to buffer it from minor environmental events that may affect more shallow rooted grasses during the growing season.

Although giant wildrye exhibited the lowest between year variation in IVOMD, bluebunch wheatgrass showed the least year-to-year variation with CP and NDF. Over an 18-year sampling period, Sneva (1982) also noted that yields of bluebunch wheatgrass were less variable than any of the other grasses in our study. When predicting annual forage yields with September-June precipitation accumulation as an independent variable, he obtained correlation coefficients ranging from 0.41 for Thurber's needlegrass to 0.84 for bluebunch wheatgrass (Sneva 1982). Highest coefficients of determination, however, were obtained when models estimated cumulative yield for all forages in the community (Blaisdell 1958, Sneva 1982).

Conclusions

Year-to-year patterns of forage quality in the northern Great Basin sagebrush steppe can be quite dynamic both within and among species. A growing season with less than average moisture may generate grass herbage that sustains a higher plane of nutrition for up to twice as many days as a growing season with abundant moisture and more than double the forage production. We suspect that when cool-season grasses begin growth with less than optimum moisture, tillers become quiescent as moisture is exhausted, and they can resume mid-summer growth if effective precipitation occurs. Conversely, when abundant moisture is available, cool season grasses quickly advance through maturity and generate an abundance of low quality reproductive stems. Subsequently, those tillers die, and the grasses enter a dormant stage where they do not respond to even elevated levels of summer precipitation.

We suggest that rangelands with a diversity of grasses, that exploit all levels of the soil profile, will provide adequate forage quality for longer time periods than pastures relying on a single species. All 7 grasses in our study supplied high quality forage in the spring, and a deeply rooted grass like giant wildrye can support high quality forage until late-July. Shallow rooted grasses like Sandberg's bluegrass, bottlebrush squirreltail, or the winter annual cheatgrass can quickly respond to mid-summer or fall precipitation that has no effect on the more deeply rooted grasses, and furnish additional high quality herbage.

Finally, while annual yields of herbage are closely correlated with yearly and sometimes seasonal precipitation accumulations, forage quality dynamics are more complex and certainly affected by seasonal events. With most of the precipitation accumulation in the northern Great Basin occurring in the colder months, land and livestock managers can, with a fair degree of certainty, predict the yields of their pastures before turnout. With an abundance of moisture, managers commonly see a rapid and predictable deterioration of forage quality typical of an arid Mediterranean climate. The quandary arrives in years when moisture accumulations will not sustain the grasses through their full development and maturity. We have shown that timely precipitation may indeed expand the period of adequate forage quality for livestock or wildlife in those instances.

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