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# Composition and production of California oak savanna seasonally grazed by sheep

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**Abstract**

**Seasonal grazing trials, conducted over 3 years at the Hopland Field Station in Mendocino County, Calif., tested the effects of 2 seasonal grazing strategies on within- and between-year production and composition in blue oak (*Quercus douglasii* H.A.) savanna understory and adjacent open annual grassland. Moderate intensity summer-fall-winter and spring-summer sheep use had few within-year effects. In contrast, production and composition varied considerably between years in both treatments. Forbs (especially legumes) decreased in open grassland and oak understory between years within both seasonal grazing regimes. This change could not have been caused by selective grazing because there were no corresponding within-year patterns. Instead, between-year changes are more likely related to nonselective effects of stocking rate and/or weather. Results from this study suggest that seasonal grazing systems offer little potential for improvement of annual range composition.**

**Key Words: selective grazing, California annual grassland, range condition**

If plant species respond differently to defoliation, selective grazing by large herbivores should alter community structure and production over time. Grazing tolerance enables plants to replace removed biomass (Caldwell et al. 1981). Thus herbivory may increase growth of defoliated plants if a compensatory growth response is stimulated (McNaughton 1983). Selective herbivory may also give a competitive advantage to ungrazed plants if defoliated neighbors are reduced in vigor or numbers (Mueggler 1972, Olson and Richards 1989). Evidence for selective grazing as a control on community structure is surprisingly weak and centered on productive perennial grasslands (Ellison 1960, McNaughton et al. 1989), with little evidence from arid and semiarid rangelands.

Between-year changes in community composition of California annual grasslands have been described in a successional framework (Heady 1977) where grass dominance follows elimination of grazing (Jones and Evans 1960). The successional sequence starts with a group of early seral species, including many forbs, and proceeds towards a vegetation dominated by taller grasses (Sampson et al. 1951). Because the application of higher stocking rates increases forbs and reduces grasses (Heady and Pitt 1979a), between-year changes have also been linked to grazing and range condition (Rosiere 1987). The forb increase does not persist after grazing pressure is reduced (Pitt and Heady 1979).

If selective grazing causes between-year changes in vegetation, then the effects must first show up as within-year differences in composition. The interpretation of within-year variation due to grazing is based on the presumed effects of selective grazing on taller species during the growing season (Pitt and Heady 1979). This idea was presented early in the development of research into annual ranges (Bentley and Talbot 1951, Heady 1958, Heady 1961), and persists today (Pendleton et al. 1983) as the basis of recommendations for seasonal grazing systems (Heady and Pitt 1979a) for improving production and composition of annual rangelands (Menke 1989).

Animals do selectively use forage in the annual type (Heady and Torrell 1959), but no published study has revealed resultant compositional differences within a growing season. If selective grazing early in the season can alter composition, then the effect will have to override the influences of weather and mulch on germination in the fall. These differences have been shown to be the major forces determining species composition without grazing (Bartolome 1979). The effects of grazing on seed supply of the dominant annuals are not important factors in determining community structure (Heady 1956, Bartolome 1979). The value of fall-winter use to improve composition of the annual grassland has long been proposed (Heady 1958), but never evaluated experimentally. The direct effects of selective grazing on botanical composition and production of California annual range remain largely speculative (Menke 1989).

Our objectives were to evaluate the influence of seasonal grazing on within- and between-year changes in annual grassland composition and production and the effect of *Quercus douglasii* H. & A. (blue oak) overstory on this grazing influence. Our approach evaluated herbaceous responses in open grassland and adjacent understory to 2 grazing seasons (summer-fall-winter and spring-summer) under moderate sheep use.

## Method

The study was conducted between fall 1982 and spring 1985 at the University of California's Hopland Field Station, located in Mendocino County, Calif., 200 km north of San Francisco. The 2,168-ha station is characterized by a mixture of open annual grasslands, oak woodlands, and shrublands (Murphy and Heady 1983). Annual precipitation, concentrated in winter, averages about 95 cm. Rainfall amount and distribution varied considerably from year to year (Fig. 1). Each year the growing season began with germinating rains in October, followed by the major winter precipitation regime. The study included years with rainfall above (1982–83), near (1983–84), and below (1984–85) the long-term average.

The 30-ha study pastures have been grazed by sheep since before the establishment of the Station in 1951. Vegetation in the pastures is 76% *Quercus douglasii* H. & A. woodland, between 10 and 75% overstory canopy cover, and 18% open grassland with <10% overstory cover. The remaining 6% consists of dense oak stands with >75% canopy cover, usually with liveoaks (*Quercus wislizenii* A. de Candolle). The soil is a silt loam classified in the ultic haploxe-

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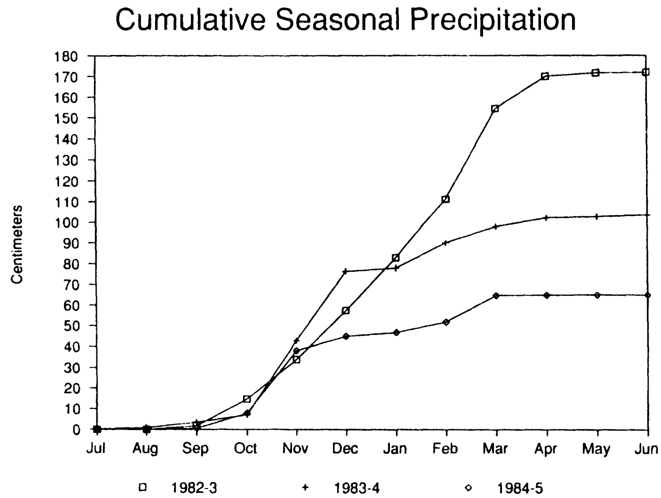


**Fig. 1. Cumulative seasonal precipitation at Hopland. The line for 1983–84 closely approximates the long-term average. Source: station records.**

roll family (McClaran and Bartolome 1989).

Sheep, generally dry ewes, grazed the 2 study pastures each year from 15 May until 15 Oct., the dormant season. Stocking rates were adjusted to produce residue levels in October within moderate stocking guidelines for annual grassland and woodland (Clawson et al. 1982). On 15 Oct. of each year the sheep were moved into the "Fall/Winter Pasture". During the fall and winter growing season, stocking was adjusted to achieve the 50% utilization typical of moderate grazing pressure. On 15 Feb. animals were moved into the adjacent "Spring Pasture", which had not been grazed since October. Seasonal use of pastures was constant over the study period.

Twenty macroplots were established at evenly distributed locations in each pasture, 10 in the open grassland ("Open Macroplots"), and 10 in blue oak understory ("Canopy Macroplots"). Cages located randomly on each macroplot to exclude grazing were moved after each year's sampling. The 75 × 75 cm cages used have been shown to have no effect on composition of annual grassland (Heady 1957). Locations selected for canopy macroplots were chosen for an overstory of blue oak, relatively large trees (>10 cm dbh), with canopy coverage of 50%. Macroplots in the open grassland areas are the same locations used since 1960 for monitoring pasture peak standing crop (Vaughn and Murphy 1982).

Quadrats 25 × 25 cm were clipped within and outside cages 4 times during the year to determine live and dead standing biomass and utilization. Sampling dates were: early October (standing dead biomass prior to first rains), late November (end of rapid fall growth), mid February (beginning of rapid spring growth), and mid May (peak standing crop, end of growing season). Species composition was estimated yearly in May with 50 point samples inside and 50 outside each cage.

Because each pasture was grazed under a different seasonal system, the analysis was designed to compare differences in plant response (grazed vs ungrazed) within pastures rather than between pastures (Pitt and Heady 1979). If vegetation shows a within-year response to either of the grazing treatments, then grazing systems warrant further testing with replication of pastures, and comparisons to continuous use for other annual grassland sites (Ratliff 1986, Stroup et al. 1986). Because cages were moved each year, differences between grazed and ungrazed samples represent a within-year effect for the grazing factor. The year factor represents the effects of the grazing factor combined with other within-year influences, including mulch amounts and weather. The interaction grazing × year represents the between-year response to within-year effects of the grazing factor. Dependent variables describing vegetation were evaluated by analyses of variance (ANOVA) using macroplots as blocks, grazing and year as factors; performed separately for each pasture and for open and canopy, and following any transformations necessary to meet assumptions of ANOVA. P< 0.1 was chosen as the level of statistical significance for hypothesis testing under ANOVA. Some means were also compared using t-tests.

## Results

### Production

Seasonal changes in aboveground herbaceous biomass reflect the typical production pattern for Mediterranean type grasslands (George et al. 1985), with rapid growth following the onset of fall rains, then slow winter growth, rapid spring growth and biomass accumulation, and finally, death and seed set. Average herbaceous biomass for the 3 years differed more between canopy and open in fall and winter than later in the spring (Table 1). Canopy herbaceous biomass in fall and winter was only one-half the open value but, by spring, canopy biomass averaged two-thirds of the open amount.

**Table 1. Aboveground herbaceous biomass in grams/m² ± Standard Error from ungrazed plots at 4 sample dates for 3 years.**

| | | Biomass | | | |
|---|---|---|---|---|---|
| Year | Type | October (n=10) | November (n=10) | February (n=20) | May (n=20) |
| | | (g/m²) | (g/m²) | (g/m²) | (g/m²) |
| 1982–83 | Open | 80±18 | 50±14/79±23 | 62±11/26±7 | 272±29 |
| | Canopy | 43±7 | 21±5/28±6 | 32±5/8±2 | 162±21 |
| 1983–84 | Open | 156±34 | 27±6/168±24 | 31±5/127±16 | 285±23 |
| | Canopy | 31±7 | 23±7/54±9 | 18±4/28±5 | 225±42 |
| 1984–85 | Open | 199±35 | 34±8/114±20 | 57±7/92±12 | 282±29 |
| | Canopy | 76±15 | 8±2/17±5 | 29±5/24±4 | 129±19 |

[1]October samples consist of dead only, November and February samples consist of live/dead, and May samples are of live material only.

Seasonal production varied among years (Table 1). The canopy fluctuated most in peak standing crop with a ratio of 0.57 between lowest (1985) and highest (1984) years in May, while the open changed little. Amount of standing crop in February appeared to have little relationship to ultimate peak standing crop. The lowest winter standing crop (in February 1984) subsequently produced the highest peak (in May 1984). In 1984–85, the canopy dropped to its lowest level while the open stayed about the same.

### Utilization

During the fall-winter period, the desired stocking to attain

**Table 2. Percent utilization of experimental pastures expressed as ratio of ungrazed-grazed to ungrazed standing crop at the end of the grazing period.**

| | Utilization | | | | | |
|---|---|---|---|---|---|---|
| | 1982–83 | | 1983–84 | | 1984–85 | |
| Grazing period | Open | Canopy | Open | Canopy | Open | Canopy |
| | (%) | (%) | (%) | (%) | (%) | (%) |
| Fall-Winter (10/15–2/15) | 42 | 51 | –1 | 54 | 61 | 39 |
| Spring 2/15–5/15 | 50 | 42 | 21 | 34 | 31 | 15 |

[1]Values are not significantly different for open and canopy within years and seasons with the exception of fall-winter 1983–84, by t-test ($p<.05$).

approximately 50% utilization was achieved, with the exception of fall 1983–84, when utilization was negligible in the open (Table 2). Use levels in the canopy and open did not differ significantly with the exception of fall 1983. Results did not show statistically significant selection or avoidance of the oak understory, although the power of the statistical test is low. This is because of the variability in difference measures and a sample size designed for estimating production and composition, not utilization.

Stocking was adjusted during the late spring and summer in an attempt to attain similar fall residue levels in the 2 pastures. However, residue levels climbed during the 3 years of the study above the target of 75–100 g/m$^2$ for open grassland (Table 1). Spring grazing intensity varied considerably among years due to rapid changes in spring standing crop, despite efforts to calibrate number of sheep and available forage.

### Grazing Effects

Grazing by sheep had little effect on spring composition compared to no grazing when years are compared (Table 3). In all but the open macroplots in the Fall-Winter pasture, misses were significantly lower when ungrazed, reflecting higher foliar cover. Total number of taxa was reduced in Fall-Winter grazed canopy macroplots, but not elsewhere, from a mean of 8.10 taxa/50 points ungrazed to 6.57 taxa/50 points grazed. In each instance of a significant species response to grazing it occurred in only a single pasture-canopy combination.

The general lack of a significant grazing effect is surprising, because of the ability of the analysis to detect significant differences. For example, legumes, a group known to be preferred by sheep (Heady and Torrell 1959), were not significantly affected by grazing, but differences as small as 2.4% cover (Spring-Grazed Canopy) and up to at most 5% cover (Fall/Winter-Grazed Open) had a 95% probability of detection by ANOVA at $p<0.05$. *Trifolium* spp., which responded significantly (ANOVA, $p<0.1$) to grazing only in the Fall/Winter-Grazed Canopy (Table 3), would have shown significant responses elsewhere for differences as small as 1.4% (Spring-Grazed Open), and at most 3.8% (Fall/Winter-Grazed Canopy). Other groups suggested as responsive to selective grazing, like tall grasses (Pendleton et al. 1983), also did not differ significantly. The tall grass group *Avena* spp., if it had changed by only 4% cover due to grazing, would likely have shown a significant difference. Another tall grass, *Bromus rigidus,* would have likely shown significant response to grazing at differences greater than 6% cover.

**Table 4. Means for cover of dependent variables that showed significant effects by ANOVA for interaction between the factors grazing and year.**

| | | | | Cover | | |
|---|---|---|---|---|---|---|
| | Grazing | | | Year | | |
| Variable | season | Type | Grazing | 1983 | 1984 | 1985 |
| | | | | (%) | (%) | (%) |
| AVE | Fall-Winter | Canopy | Grazed | 0.66 | 2.80 | 3.20 |
| | | | Ungrazed | 4.00 | 1.60 | 3.80 |
| FES | Spring | Canopy | Grazed | 15.34* | 27.20* | 14.60* |
| | | | Ungrazed | 20.34* | 10.17* | 20.00* |
| OGGL | Spring | Open | Grazed | 21.34 | 24.60 | 8.40 |
| | | | Ungrazed | 17.34 | 34.40 | 17.00 |
| OGGL | Fall-Winter | Canopy | Grazed | 2.00 | 7.60 | 3.40 |
| | | | Ungrazed | 4.66 | 4.20 | 8.20 |
| TG | Spring | Canopy | Grazed | 41.66 | 55.20 | 37.40 |
| | | | Ungrazed | 38.00 | 48.80 | 55.60 |

[1]Means for variable significantly affected by the interaction at $p<0.05$ are marked with *, others are significantly affected at $0.05<p<0.10$.
[2]Variables named and analyzed are listed in Table 3.

Only 2 grass species and the groups Other Grasses and Total Grasses showed differences due to the interaction between grazing treatment and year (Table 4). Examination of the means for the interaction Year × Grazing shows that the grazing effect, when present, differs among years, even for the same species. For example, *Vulpia* spp. were more abundant under Spring grazing in the canopy in 1984, but the reverse was true for 1983 and 1985.

### Year Effects

Species composition differed among years; a majority of taxa showed a significant year effect (Table 5). Total cover (increased

**Table 3. Means for dependent variables that showed significant effects by ANOVA for the grazing factor. Values for taxonomic groups represent cover.**

| | Cover by pasture and type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Summer-Spring Open | | Summer-Spring Canopy | | Fall-Winter Open | | Fall-Winter Canopy | |
| Dependent variables | Grazed | Ungrazed | Grazed | Ungrazed | Grazed | Ungrazed | Grazed | Ungrazed |
| | (%) | | | | | | | |
| AVE | | | | | | | | |
| Brmo | | | | | | | | |
| Brri | | | | | | | | |
| FES | | | 19.04 | 25.24 | | | | |
| HOR | | | | | | | 1.04 | 2.20 |
| Taas | 12.04* | 9.38* | | | | | | |
| OGGL | | | | | | | | |
| TG | 47.60 | 45.20 | | | | | | |
| TRI | | | | | | | 0.84 | 2.32 |
| Mepo | | | | | | | | |
| OL | | | | | | | | |
| Trsu | | | | | | | | |
| TL | | | | | | | | |
| ERO | | | 0.62 | 0.14 | | | | |
| Capy | | | | | 0.26 | 0.0 | | |
| TNLF | | | | | | | | |
| Miss | 23.94* | 18.16* | 32.84 | 24.80 | | | 42.28 | 34.88 |
| Taxa | | | | | | | 6.57* | 8.10* |

[1]Means for variables significantly affected by grazing at $p<0.05$ are marked with *, other values were significantly affected at $0.05<p<0.10$.
[2]Taxonomic groups, with variable names in parentheses are: *Avena* spp. (AVE), *Bromus mollis* (Brmo), *Bromus rigidus* (Brri), *Vulpia* spp. (FES), *Hordeum* spp. (HOR), *Taeniatherum asperum* (Taas), Other grasses and grass-like (OGGL), Total Grasses (TG), *Trifolium* spp. (TRI), *Medicago polymorpha* (Mepo), Other legumes (OL), *Trifolium subterraneum* (Trsu), Total Legumes (TL), *Erodium* spp. (ERO), *Carduus pycnocephalus* (Capy), Total Non-Legume Forbs (TNLF), and other than live plant (Miss). Taxa is number of species in a 50 point sample.

Table 5. Means for dependent variables that showed significant effects by ANOVA for the year factor. Values for taxonomic groups represent cover.

| | Cover | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Spring grazed open | | | Spring grazed canopy | | | Fall/winter grazed open | | | Fall/winter grazed canopy | | |
| Dependent variable | 1983 | 1984 | 1985 | 1983 | 1984 | 1985 | 1983 | 1984 | 1985 | 1983 | 1984 | 1985 |
| | % | | | | | | | | | | | |
| AVE | 7.16 | 3.40 | 4.40 | 5.00 | 2.50 | 1.60 | | | | 2.34 | 2.20 | 3.50 |
| Brmo | 16.50* | 14.10* | 9.30* | | | | | | | 6.00 | 2.80 | 4.90 |
| Brri | | | | 3.00* | 6.70* | 8.70* | | | | 12.16 | 10.60 | 6.50 |
| FES | 0.16* | 0.20* | 1.20* | 39.84* | 23.60* | 25.00* | 1.16* | 1.00* | 1.90* | 1.00* | 1.50* | 7.50 |
| HOR | | | | | | | 0.50* | 0.0* | 0.0* | 1.00* | 2.50* | 1.10* |
| Taas | 3.84* | 14.10* | 14.20* | | | | | | | | | |
| OGGL | 19.34* | 29.50* | 12.70* | 5.50* | 12.70* | 5.70* | 22.50* | 25.40* | 16.00* | 3.34 | 5.90 | 5.80 |
| TG | 47.00* | 62.00* | 42.20* | 39.84 | 52.00 | 46.50 | 30.88 | 44.44 | 43.78 | | | |
| TRI | 3.66* | 1.90* | 0.60* | | | | 11.84* | 2.10* | 3.70* | | | |
| Mepo | 9.82* | 1.60* | 0.70* | 2.00 | 0.50 | 0.00 | 1.34* | 1.20* | 0.10* | 3.34* | 1.10* | 1.50* |
| | | | | | | | 2.16 | 1.00 | 1.20 | | | |
| TLeg | 15.50* | 5.10* | 1.90* | 4.50* | 1.90* | 0.20* | 18.66* | 4.80 | 6.00* | 5.84* | 2.70* | 4.30* |
| ERO | 11.16* | 4.90* | 11.20* | | | | | | | | | |
| Capy | 0.84 | 0.10 | 0.00 | 11.84* | 4.50* | 1.70* | | | | | | |
| TNLF | 28.84* | 16.50* | 19.10* | 26.16* | 26.30* | 8.60* | | | | 39.16* | 34.50* | 17.00* |
| Miss | 8.34* | 16.40* | 38.40* | 21.16* | 20.60* | 44.70* | 15.16* | 24.10* | 28.70* | 14.58* | 18.60* | 24.70* |
| Taxa | 8.75* | 9.00* | 7.00* | 7.60* | 9.75* | 6.30* | | | | 7.30 | 7.80 | 7.00 |

[1]Means for variables significantly affected by year at $p<0.05$ are marked with *, other values were significantly affected at $0.05<p<0.10$.
[2]Variables named and analyzed are listed in Table 3.

misses) declined significantly among years. Legumes generally declined, with a nearly complete loss of *Medicago polymorpha* in the open, and a decline of *Trifolium* spp. in the open. Canopy legumes declined significantly in the Spring grazed pasture, but not in the Fall-Winter grazed pasture. Forbs also generally declined, with a significant decline of *Carduus pycnocephalus* in the Spring grazed pasture. Relative grass dominance increased during the study period.

## Discussion and Conclusions

Both experimental pastures showed considerable differences in production and composition between the open and canopy seasonally and among years. The degree of variability was typical for peak standing crop in woodland canopy (Heady and Pitt 1979b), and for composition and production of open grassland (Talbot et al. 1939, George et al. 1989), and improved grassland (Vaughn and Murphy 1982). Understory standing crop varied more within and between years than the open grassland.

Some range managers suggest that winter production is increased under the blue oak canopy, particularly in the San Joaquin Valley (Duncan and Reppert 1960, McClaran and Bartolome 1989), but also in the Northern Sierra Nevada (Jackson et al. 1988). These observations did not hold for Hopland, where canopy production was significantly lower than the open for all measurements in fall, winter, and spring.

The canopy and open have very different species assemblages which retain their overall differences from year-to-year. The annual grassland has been observed to have different composition in the open and the oak understory (McClaran and Bartolome 1989). In this study the 2 herbaceous types were not only different in composition, but also responded differently to grazing and year. The species differences between open grassland and oak understory suggest that, at peak standing crop, forage quality will be better in the open grassland because the understory contains several low value dominants (Sampson et al. 1951); yet the especially undesirable *Taeniatherum asperum* does not occur under the canopy. However, for most of the growing season, differences in composition will have only a negligible effect on forage quality because the plants are in the vegetative stage and of similar palatability. By late spring, the peak standing crop in the open grassland had better overall composition as livestock forage than under the canopy. Surprisingly, these differences in composition were not sufficient to produce large differences in utilization between the open and canopy.

This study revealed few within-year differences in plant cover due to grazing in open grassland or under the oak canopy, a result that contrasts with predicted differences based on diet studies (Heady and Torrell 1959), and with evidence for changes in composition between years due to grazing intensity (Pitt and Heady 1979). Selective utilization during the fall-winter, which had been postulated to affect composition later in the season (Pendleton et al. 1983), did not materially change spring plant composition compared to nonuse. Composition may have been altered during or immediately following fall-winter grazing but, by spring, species differences between grazed and ungrazed plots, even when significant, were small and not of managerial importance.

Spring grazing, which had been evaluated extensively in other studies and had been shown to have an effect between years (Pitt and Heady 1979), had few within-year effects in this study. Even the rare significant differences were small. Although use levels in spring were lower than originally planned, the results are consistent with those of Pitt (1975), who reported few differences in composition under spring use levels of about 50%. The lack of within-year compositional differences unexpectedly showed that selective grazing use during the rapid spring growth period did not affect within-year forb (including legume) abundance. Because within-year effects are few, the numerous between-year effects must be caused by something else. This result supports the dominant roles of weather patterns and mulch levels in determining composition and shows that selective grazing cannot substantially alter composition on unimproved annual ranges under moderate use.

When between-year grazing effects are analyzed as the interaction between years and grazing treatment, only total cover and 4 species showed significant responses. Under moderate levels of spring and/or summer utilization, fall residue or litter in the open increased over the course of the study. This litter build up should have favored *Bromus rigidus* and *Taeniatherum asperum* (Heady et al.). *Bromus rigidus* decreased significantly between years under fall/winter use, as predicted in another study (Pitt and Heady

1978), but only under canopy, not in open. *Taeniatherum asperum* increased in the open between years in the spring-grazed pasture.

The decrease in legumes over the course of the study probably reflected both poor legume years in 1984 and 1985 and the generally lower levels of open grassland utilization over the study period. Legumes fared worst in the spring-grazed pasture, a result consistent with the observation that legumes do poorly without fall-winter use (Murphy et al. 1973). However, the lack of a significant grazing effect in spring-grazed pastures or on open macroplots in fall/winter-grazed suggests that the overall legume decline between years is not related to selective grazing within years.

Management of California grasslands for improved botanical composition and plant and animal production has always been a tempting goal. Substantial improvements have been achieved through fertilization and seeding on suitable sites (Menke 1989). Management of residual dry matter has been proven to be an effective tool for maintenance of productivity and acceptable composition (Bartolome et al. 1980, Clawson et al. 1982). None of these responses depend on within-year effects of grazing.

The potential for range improvement under seasonal grazing management on annual range is small. This study emphasized repeated summer/fall/winter and summer/spring grazing under moderate use. The best that the manager can do on unimproved pastures is to develop grazing practices which utilize forage of appropriate quality when needed by animals and to regulate intensity of use as measured by fall mulch levels. Seasonal grazing at moderate utilization levels offers little potential for changing within-year production or composition on unimproved annual grasslands and savannas.

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