Herbivore effects on seeded alfalfa at four pinyon-juniper sites in central Utah

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Abstract

Effects of rabbits (*Lepus californicus, Sylvilagus* spp.), mule deer *(Odocoileus hemionus)*, and livestock on seeded alfalfa *(Medicago sativa)* were studied on 4 sites in central Utah. Sites were dominated by pinyon pine *(Pinus edulis)*-and Utah juniper *(Juniperus osteosperma)* and were doubled-chained and seeded with a mixture of grasses, forbs, and shrubs between 1959 and 1962. A 4-way exclosure was built on each site in 1962 which included the following treatments: (1) control (rabbits, deer, and livestock excluded), (2) rabbit access, (3) deer access, and (4) rabbit plus deer access. The fifth treatment (outside the exclosure) was accessible to rabbits, deer, and livestock. Alfalfa density and production were estimated at 1- to 5-year intervals between 1963 and 1986. Alfalfa growth form was measured in 1986. Stand densities declined from 0.5 to 8.5 plants/m² to 0.5 to 2.5 plants/m² during the 23-year sampling period. Reproduction by seed was not evident. Alfalfa production fluctuated greatly (4 kg/ha to 4,104 kg/ha) with precipitation and decreased with increased herbivore access. Treatment effects varied. Rabbits had a negative effect on alfalfa density at 2 sites, but no effect on alfalfa production. Deer use had inconsistent effects on alfalfa density, but reduced alfalfa production at 2 sites. The addition of livestock use reduced alfalfa density at 1 site, and alfalfa production at 3 sites. Grazing treatments had a marked effect on alfalfa growth form. Decreases in height and increases in basal cover were associated with increased herbivore access. Results of this study indicate that alfalfa can be an important and persistent component of seeding mixtures used on semiarid pinyon-juniper ranges.

Key Words: ***Medicago sativa*, alfalfa, range seeding, herbivore effects, exclosures**

Pinyon-juniper woodlands occupy approximately 7.1 million ha of the Great Basin of the Western United States (Tueller et al. 1979). The pinyon-juniper type is important habitat for wild ungulates and rangeland for domestic livestock, but forage values have suffered from extensive depletion of understory vegetation. This depletion has been attributed to a number of factors, including overgrazing, fire suppression, and dominance by woody species (Arnold et al. 1964, Tausch et al. 1981).

A great deal of effort has been directed toward increasing forage production on pinyon-juniper lands. Most pinyon-juniper modification projects have involved removal of the tree canopy by mechanical means (chaining, cabling, or dozing), fire, or herbicides. Seeding is often necessary where desirable forage species are absent or too sparse to respond to treatment.

Alfalfa *(Medicago sativa)* is the most commonly seeded forb on pinyon-juniper modification projects (Plummer et al. 1968, Rumbaugh 1983). It is highly palatable and nutritious to wild and domestic herbivores (Dietz et al. 1962, White and Wight 1984). Rangeland alfalfa varieties have been successfully established on pinyon-juniper sites receiving >25 cm annual precipitation, and are compatible with other species commonly used in mixtures (Stevens 1983).

Herbivore use can be an important influence on the survival and productivity of rangeland alfalfa seedings (Ries 1982). Published information on the effects of grazing on alfalfa in the pinyon-juniper type is limited and largely descriptive. Phillips (1979) compared alfalfa production in plots protected from grazing by deer and livestock with plots accessible to these herbivores. Rumbaugh and Pedersen (1979) evaluated the effects of grazing by rabbits, deer, and livestock on alfalfa survival. Rabbit damage to seeded alfalfa has frequently been observed (Tausch 1973, Lavin and Johnsen 1977, Phillips 1977, Johnsen and Gomm 1981).

Growth forms of alfalfa grazed by livestock have been studied only under tame pasture conditions (Heinrichs 1954, Kehr et al. 1963, Daday 1968, Gdara 1985). Results of these studies indicated that alfalfa persistence under grazing is closely related to growth form.

This project was undertaken to quantify wild and domestic herbivore effects on the density, production, and growth form of seeded alfalfa in a semiarid rangeland. Data were collected between 1963 and 1986 from exclosures and adjacent unexclosed areas at 4 chained and seeded pinyon-juniper sites in central Utah.

Methods

Study Sites

The study was conducted at 4 pinyon pine *(Pinus edulis)*—Utah juniper *(Juniperus osteosperma)* big game range modification projects implemented between 1959 and 1962 in Sanpete County, central Utah. They are 242 to 400 ha in size, at elevations of 1,755 to 2,143 m, with long-term average annual precipitation of 29 to 46 cm. Soils are limestone-derived cobbly loams in the Fontreen Series (Soil Conservation Service 1981). Prior to tree removal, all 4 sites were dominated by mature pinyon-juniper stands with depleted understory vegetation. All 4 sites were double-chained in October or November. Between chainings a seed mixture of native and introduced grasses, forbs, and shrubs was applied by fixed-wing aircraft (Table 1). Alfalfa was the most heavily seeded forb, at rates of 0.9 to 2.2 kg/ha. A mixture of 3 cultivars ('Ladak', 'Nomad', and 'Rambler') was used. Post-treatment vegetation on all sites was dominated by seeded perennial grasses.

Post-treatment grazing by domestic livestock varied among the 4 sites. All were rested for 2 to 12 years to enhance establishment of seeded species and recovery of native vegetation (Table 2). Following rest, use was limited to spring (May and June) at stocking rates of 1 to 5 ha per animal unit month (AUM). However, trespass grazing occasionally occurred. Most livestock use has been by cattle (Table 2).

A 4-way exclosure was constructed on each site in 1962 (Fig. 1). The 4 grazing treatments inside the exclosure were: (1) control (rabbits, deer, and livestock excluded), (2) rabbit access, (3) deer

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The U.S. Department of Agriculture, Forest Service, Intermountain Research Station facilitated this study through cooperative agreements 12-11-204-29 with the Utah Division of Wildlife Resources (UDWR) and 22-C-5-INT-60 with Colorado State University and UDWR. Funds were also provided through Federal Aid in Wildlife Restoration Project W82R Study 7. A. Perry Plummer, Stephen B. Monsen, and Donald R. Christensen were responsible for initiation of this study and early data collection. Three anonymous reviewers provided valuable comments on the manuscript.
Manuscript accepted 16 March 1989.

Table 1. Seed mixtures and rates (kg/ha) applied on 4 pinyon-juniper chaining study sites in central Utah.

Species	Location[1] EM	MF	MYF	SH
Fairway wheatgrass *(Agropyron cristatum)*	3.5	3.5	3.5	3.5
Intermediate wheatgrass *(Agropyron intermedium)*	0.9	1.8	0.9	0.9
Western wheatgrass *(Agropyron smithii)*	0.4	—	0.4	0.4
Pubescent wheatgrass *(Agropyron trichophorum)*	0.4	1.8	0.4	0.4
Smooth brome *(Bromus inermis)*	1.8	0.9	1.8	1.8
Russian wildrye *(Psathyrostachys junceus)*	1.8	0.9	1.8	1.8
Alfalfa *(Medicago sativa)*	2.2	0.9	2.2	1.8
Yellow sweetclover *(Mellotus officinalis)*	0.9	0.4	0.9	0.9
Small burnet *(Sangusorba minor)*	0.4	—	0.4	0.4
Big sagebrush *(Artemisia tridentata)*	0.4	0.4	0.4	0.4
Rubber rabbitbrush *(Chrysothamnus nauseosus)*	—	0.4	—	—

[1]EM = E. Mayfield, MF = Manti Face, MYF = Mayfield Face, SH = S. Hollow.

Table 2. Grazing history 1963 to 1986 of 4 pinyon-juniper chaining study sites in central Utah.

Site	Post seeding rest period (years)	No. Years Grazed Cattle	Sheep
E. Mayfield	7	13	—
Manti Face	12	5	3
Mayfield Face	2	18[1]	—
S. Hollow	5	14	2

[1]Includes both cattle and sheep use.

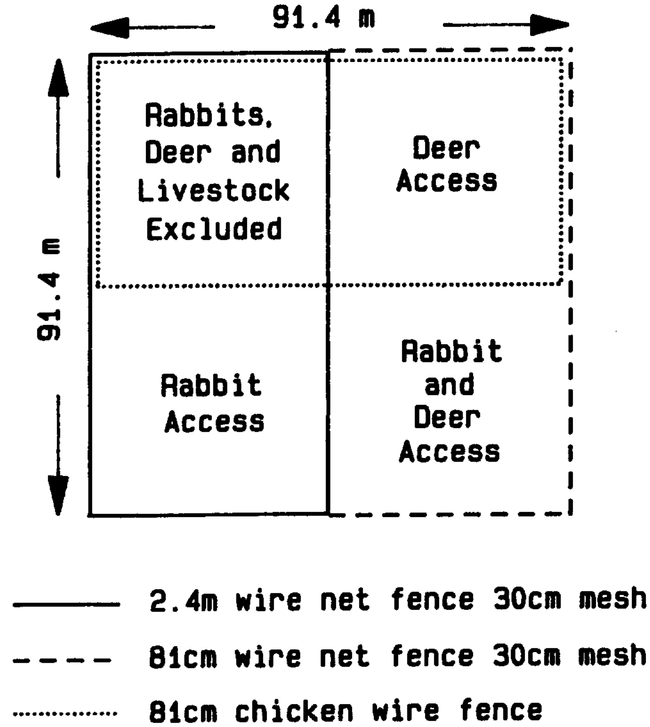

Fig. 1. *Four-way exclosure design used at 4 pinyon-juniper chaining study sites in central Utah.*

access, and (4) rabbit plus deer access. The fifth treatment (outside the exclosure) was accessible to rabbits, deer, and livestock.

Data Collection and Analysis

At each site, a set of 5 permanent 30.5- by 0.3-m belt transects was randomly located within each of the 5 grazing treatments. Each transect was divided into 10 subplots of 3.1- by 0.3-m. Sampling occurred at 1- to 5-year intervals between 1963 and 1986, usually in early July. The number of alfalfa plants (seedling and mature) in each subplot was tallied, along with an ocular estimate of above-ground alfalfa production. Clipped alfalfa samples of known weight were used to improve accuracy of biomass estimation.

Data from each site were analyzed separately due to unequal sample sizes (sampling years) and nonconcurrent sampling. Yearly subplot data within each transect were pooled. Because exclosures were not replicated on each site (a common problem in grazing studies at the time this project was initiated), the 5 transects within each treatment were used as independent sampling units for statistical analysis. Interpretation of these data assumed that site differences were small relative to treatment effects, due to careful location of the exclosures. Hawkins (1986) and Guthery (1987) noted that valuable inferences can still be drawn from experimental designs lacking true replication.

The effects of grazing treatments on alfalfa density and production were tested with Repeated Measures Analysis of Variance (Winer 1971). Control, rabbit, deer, and rabbit plus deer treatments were analyzed in a 2 $\times$ 2 factorial design. Rabbit plus deer effects were tested against rabbit plus deer plus livestock effects in a 1-way design. One or more years of data from each site were omitted from the latter analysis due to missing observations. All main (grazing treatment) effects were tested as single degree of freedom contrasts. If the ANOVA indicated significant ($p \leq 0.05$) treatment effects and nonsignificant ($p \geq 0.10$) confounding interactions, means within each sampling year were compared with Tukey's test at the 0.05 significance level. Type I error probabilities for within-subject effects (year and year $\times$ treatment interactions) were based on a Multivariate Analysis of Variance Wilk's Lambda F-approximation (LaTour and Miniard 1983).

In June 1986, a random sample of 50 alfalfa plants at full-bloom stage was selected from each grazing treatment at 3 sites (E. Mayfield, Manti Face, and S. Hollow). Height of each plant was measured to the nearest centimeter. Basal cover of each plant was measured to the nearest 100 cm^2 within a 40- by 50-cm cover frame divided into 10- by 10-cm squares. Grazing treatment effects were tested with Analysis of Variance in a completely random design. Where the ANOVA indicated significant ($p \leq 0.05$) treatment effects, means were separated with Tukey's test at the 0.05 level of significance.

Results

Density

Alfalfa density changed considerably during the 23-year sampling period (Figs. 2, 3). Reproduction by seed was not evident. Density at the time of initial sampling (1 to 4 years post-seeding) ranged from 0.5 to 7.5 plants/m^2. There were considerable differences between treatments at 3 of the 4 sites. Density at the Manti Face site was much higher than at the other sites, despite a lower seeding rate (Table 1).

Downward density trends across most treatments were observed over much of the sampling period at 3 sites (Figs. 2, 3). This was reflected in a significant year effect found at all sites in the ANOVA for rabbit and deer treatments and at E. Mayfield and Mayfield Face in the ANOVA for livestock effects. However, alfalfa density increased between 1963 and 1967 in most treatments at all sites except Manti Face. The 1967 measurements were the highest recorded during the sampling period for most treatments at all sites. Density at E. Mayfield and Mayfield Face declined after the 1967 peak, and then stabilized. Alfalfa density at Manti Face has declined steadily since 1964. Density at the S. Hollow site has

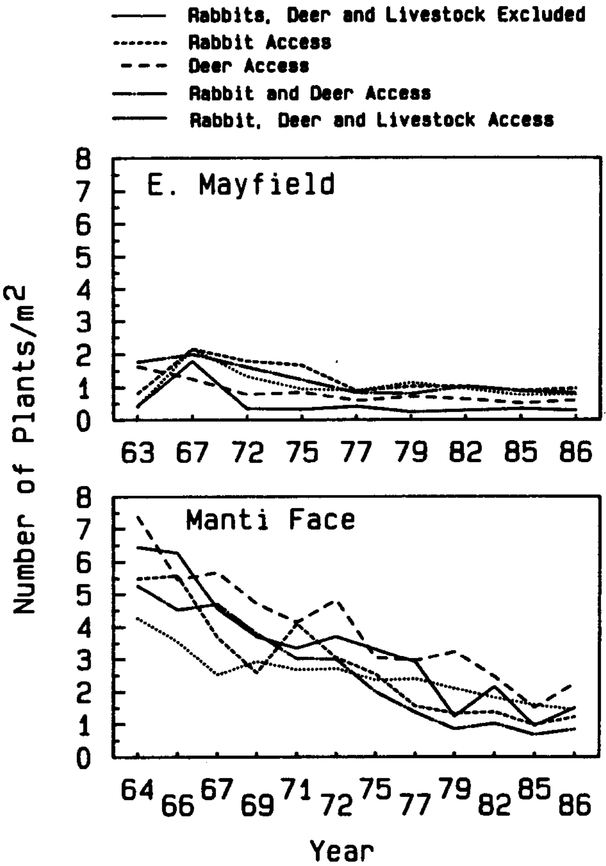

Fig. 2. *Density of seeded alfalfa 1963 to 1986 at E. Mayfield and Manti Face pinyon-juniper chaining study sites in central Utah.*

fluctuated, but not declined appreciably. Mean alfalfa density for all sites and treatments in the final sampling (1986) was 0.5 to 2.5 plants/m².

Effects of rabbit and deer use on alfalfa density varied among sites. Significant rabbit effects were found at E. Mayfield and Mayfield Face, where alfalfa densities under rabbit use were significantly lower than in the control in 1 of 9 sampling years and 2 of 8 sampling years, respectively. Deer effects were significant at 2 sites. Alfalfa densities were significantly lower than the control in 3 of 8 sampling years at Mayfield Face, but significantly higher in 3 of 8 sampling years at S. Hollow. Year $\times$ rabbit interactions were significant at all sites except Manti Face, while significant year $\times$ deer interactions were found at all sites.

Alfalfa density under grazing by rabbits, deer, and livestock was lower than under the other treatments for much of the sampling period at E. Mayfield (Fig. 2). Density in the rabbit plus deer treatment was significantly higher in 5 of 8 sampling years. Significant year $\times$ livestock interactions were also found at this site.

Production

Large year to year fluctuations in alfalfa production were observed across all sites and treatments, and coincided with changes in precipitation (Figs. 4-7). The highest production occurred in 1985 and 1986, the wettest years during the sampling period. The ANOVA for rabbit and deer treatments indicated significant year effects at all sites, while the ANOVA for livestock effects indicated significant year effects at E. Mayfield and Mayfield Face.

Mean alfalfa production (all years combined) generally decreased with increased herbivore access (Fig. 8). Mean production was

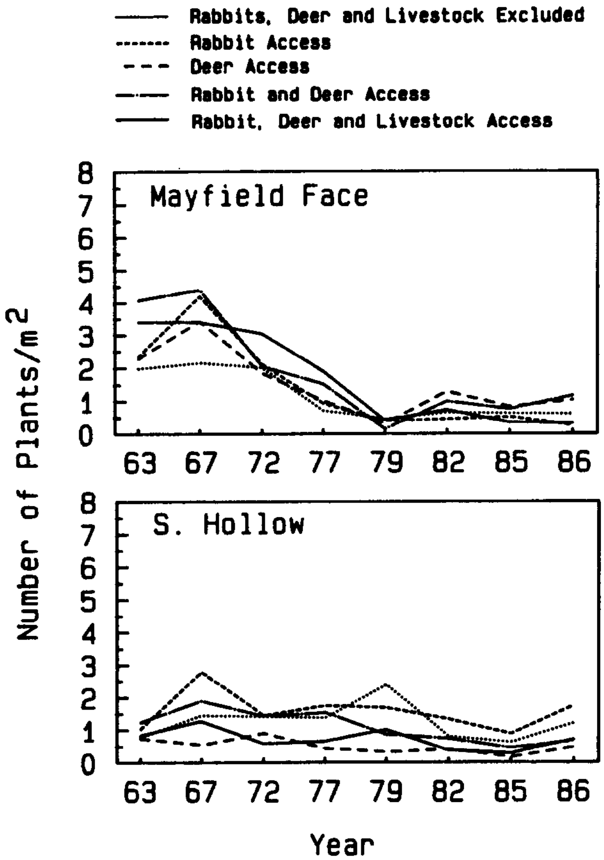

Fig. 3. *Density of seeded alfalfa 1963 to 1986 at Mayfield Face and S. Hollow pinyon-juniper chaining study sites in central Utah.*

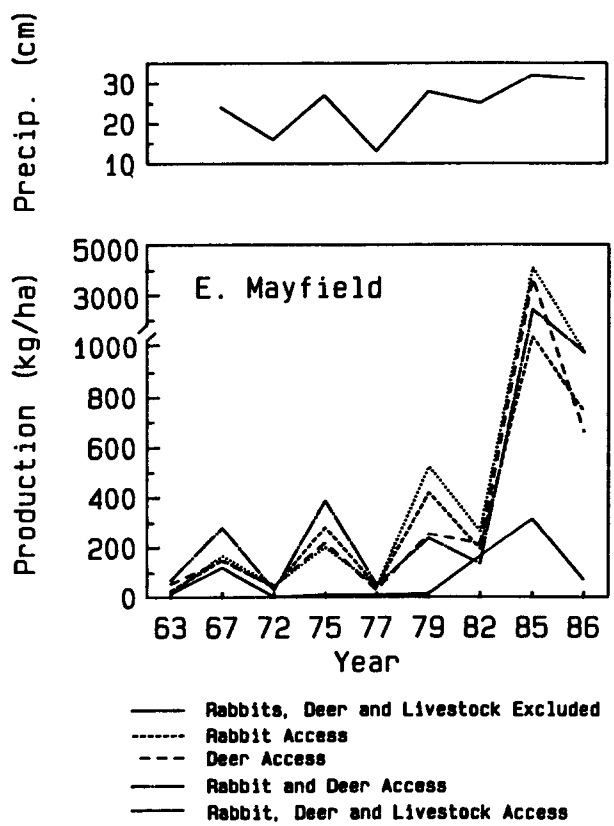

Fig. 4. *Precipitation (October to May, cm) and alfalfa production (kg/ha) 1963 to 1986 under 5 grazing treatments at E. Mayfield pinyon-juniper chaining study site in central Utah.*

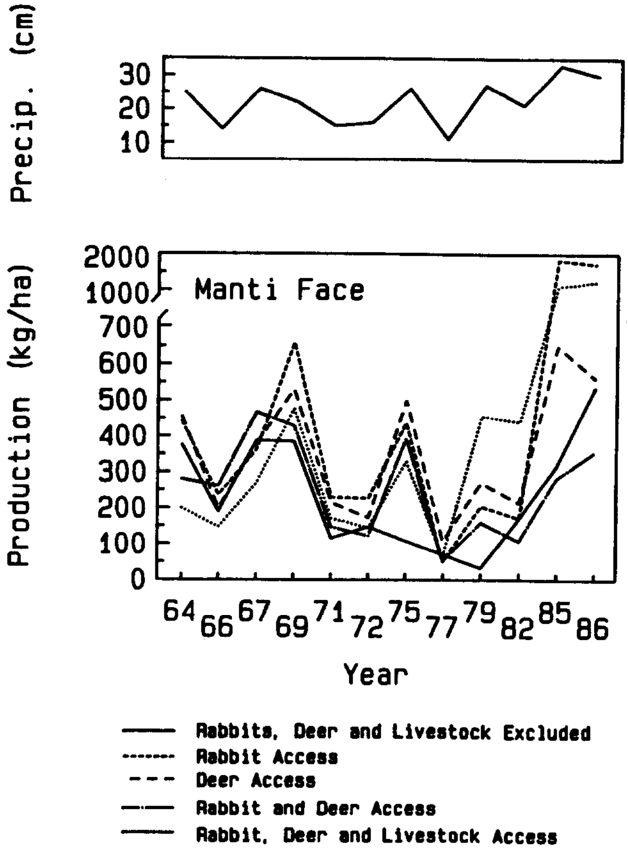

Fig. 5. *Precipitation (October to May, cm) and alfalfa production (kg/ha) 1964 to 1986 under 5 grazing treatments at Manti Face pinyon-juniper chaining study site in central Utah.*

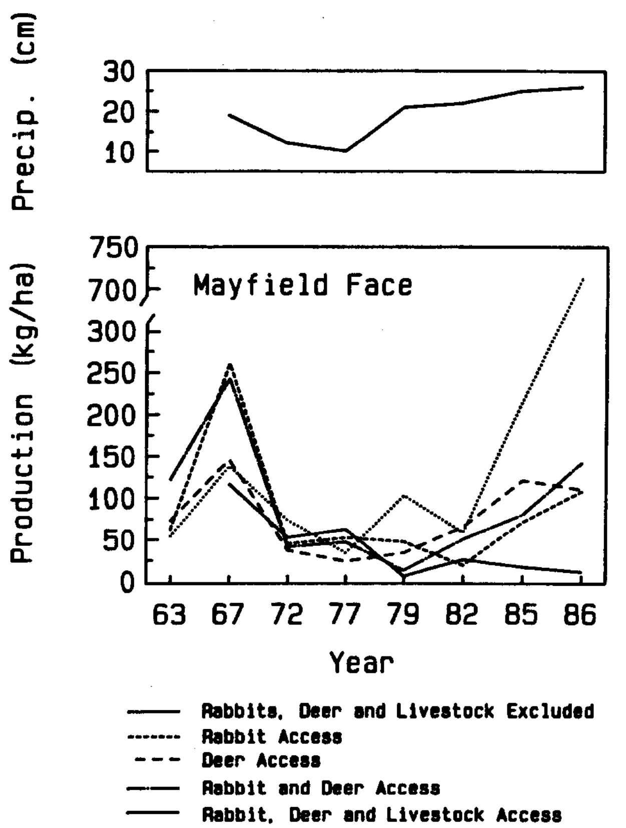

Fig. 6. *Precipitation (October to May, cm) and alfalfa production (kg/ha) 1963 to 1986 under 5 grazing treatments at Mayfield Face pinyon-juniper chaining study site in central Utah.*

highest in the control treatment at all sites except Manti Face, where the rabbit treatment had the highest mean production. Negative effects of rabbit use approached significance (p=0.057) only at Mayfield Face.

Mean production in the deer treatment was less than in control and rabbit treatments at all sites (Fig. 8). Mean production under deer use was significantly lower in 4 of 8 sample years at E. Mayfield, and 4 of 9 years at S. Hollow. Comparisons at Manti Face and Mayfield Face were precluded by significant rabbit × deer interactions.

Significant year × rabbit interactions were found at all sites except E. Mayfield. Year × deer interactions were significant at all sites except Manti face.

Annual alfalfa production at all sites was often lowest in the rabbit plus deer plus livestock treatment (Figs. 4-7). Mean production (all years combined) in this treatment was also lower than under the other treatments at all sites (Fig. 8). The addition of livestock to rabbit plus deer use significantly reduced alfalfa production at 3 sites. Production in the rabbit plus deer treatment was significantly greater in 7 of 8 sampling years at E. Mayfield and 3 of 7 years at Mayfield Face and S. Hollow. Significant year × livestock interactions were found at E. Mayfield and Mayfield Face.

Growth Form

Consistent differences in growth form were observed after 23 years under the 5 grazing treatments. Plant height at full-bloom ranged from 7 to 115 cm, and decreased with increased herbivore access (Fig. 9). Mean plant heights were significantly different for all treatments except deer and rabbit plus deer (Table 3).

Basal cover of individual alfalfa plants at full-bloom ranged from 100 to 2,900 cm², and generally increased with increased herbivore access (Fig. 10). However, lateral spread was less in the rabbit plus deer plus livestock treatment than in the deer and rabbit plus deer treatments. Mean basal cover per plant was significantly different for all treatments (Table 3).

Table 3. Height and basal cover per plant (mean, SE) of seeded alfalfa at full bloom after 23 years under 5 grazing treatments at 3 pinyon-juniper chaining study sites in central Utah.

Treatment	Height (cm) Mean[1]	Height (cm) SE	Basal Cover (cm²) Mean[1]	Basal Cover (cm²) SE
Rabbits, deer, and livestock excluded	78.91a	1.03	368.67a	13.81
Rabbit access	68.77b	1.39	776.73b	55.61
Deer access	41.97c	1.10	1376.00c	50.37
Rabbit and deer access	39.83c	1.01	1541.33d	46.45
Rabbit, deer, and livestock access	29.95d	0.87	1135.33e	44.88

[1]Means followed by the same letter are not significantly different (Tukey's test 735 df, $p \leq 0.05$).

Discussion

Density

In the initial sampling, alfalfa density at all 4 sites showed no consistent pattern among treatments, and could have reflected unequal establishment of plants, site effects, or differences in herbivore use. The higher overall density at Manti Face probably resulted from better site preparation, for example, greater seedbed disturbance and non-frozen soil during chaining. Establishment could have also been enhanced by more favorable post-seeding growing conditions. Density at E. Mayfield and S. Hollow could have been reduced by greater herbivore use prior to construction of

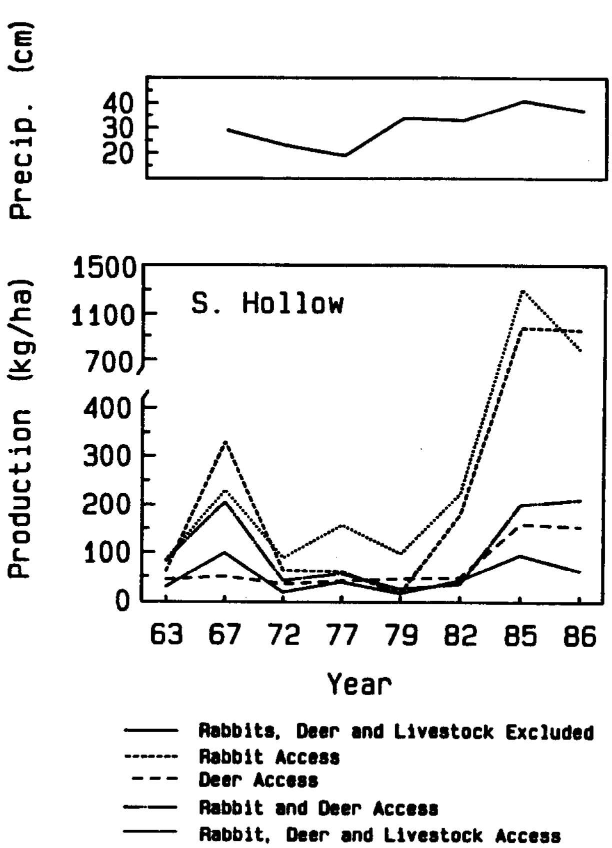

Fig. 7. *Precipitation (October to May, cm) and alfalfa production (kg/ha) 1963 to 1986 under 5 grazing treatments at S. Hollow pinyon-juniper chaining study site in central Utah.*

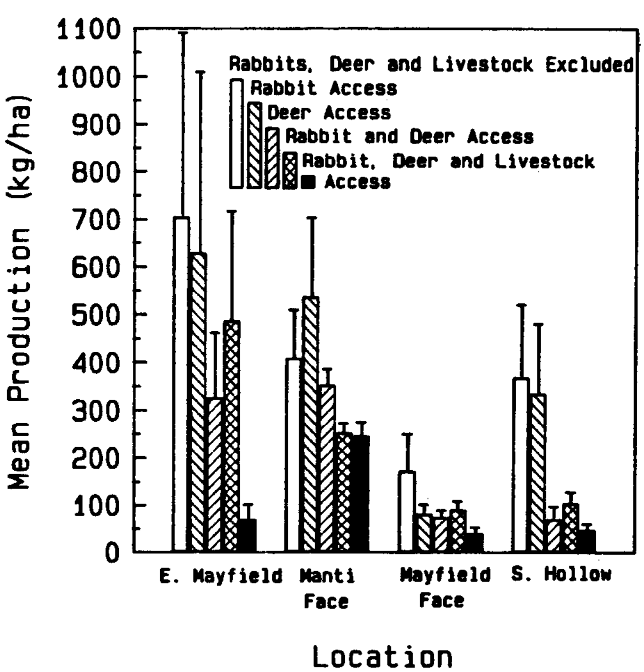

Fig. 8. *Mean production (kg/ha) of seeded alfalfa (mean, SE) 1963 to 1986 under 5 grazing treatments at 4 pinyon-juniper chaining study sites in central Utah.*

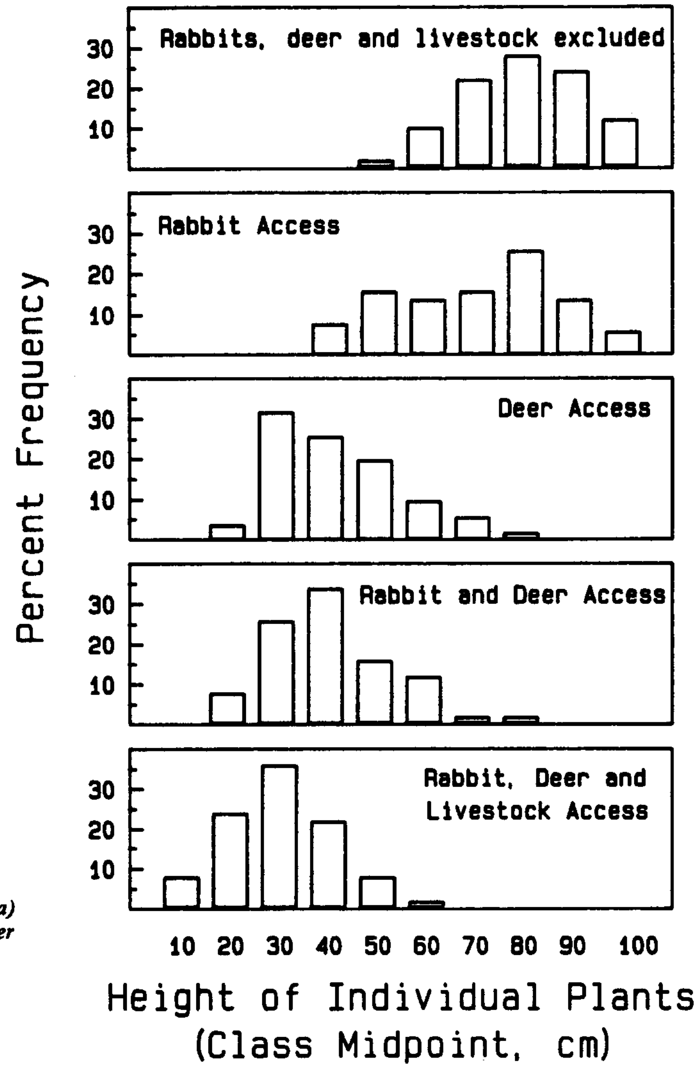

Fig. 9. *Height distribution of individual alfalfa plants at full-bloom in 1986 after 23 years under 5 grazing treatments at 3 pinyon-juniper chaining study sites in central Utah (n=150 plants/treatment, 50 from each site).*

the exclosures.

Concurrent stand losses observed for all treatments at 3 of the 4 sites suggest that herbivore use can be a secondary factor in alfalfa survival. Results of other studies indicate high initial establishment followed by rapid decline is typical on semiarid sites, even when protected from grazing. Holechek et al. (1982) found alfalfa mortality rates of 84 to 86% over 5 years on a southern Montana mined-land reclamation seeding. Rumbaugh and Pedersen (1979) attributed similar declines on central Utah big sagebrush *(Artemisia tridentata)* and pinyon-juniper sites to drought stress and competition with other seeded species. Intraspecific competition may also become important at high densities. Rumbaugh (1982) observed greater post-seeding mortality in alfalfa stands with higher initial density (19 plants/m^2) than in those with lower initial density (10 plants/m^2). This may explain the consistent declines observed at Manti Face.

Alfalfa mortality in rangeland seedings has also been attributed to damage by pocket gophers (Bleak 1969, Townsend 1982, McGinnies and Townsend 1983). Gopher activity was not measured in this study, so the impact could not be assessed.

Similarities in alfalfa density across all sites and treatments 24 to 27 years after seeding suggest that 2.5 plants/m^2 may be a maxi-

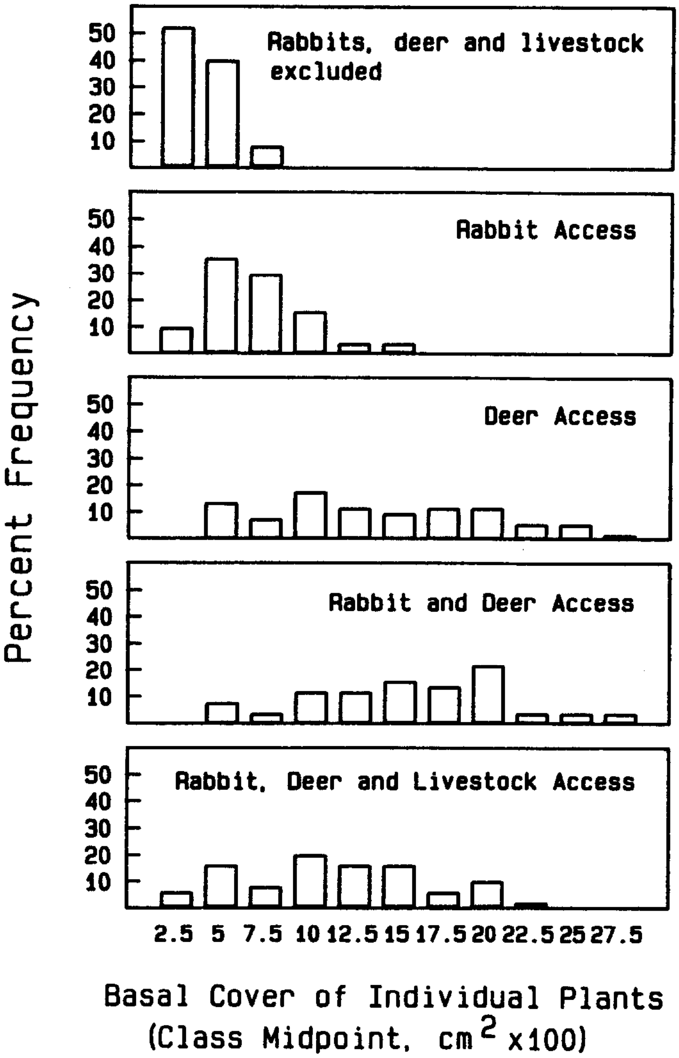

Fig. 10. *Basal cover distribution of individual alfalfa plants at full-bloom in 1986 after 23 years under 5 grazing treatments at 3 pinyon-juniper chaining study sites in central Utah (n=150 plants/treatment, 50 from each site).*

mum persistence density for these sites. Rumbaugh (1982) observed stand declines from 10 to 19 plants m^2 to 1.5 to 1.7 plants/m^2 over a 2-year period on a central Utah dryland seeding. Leckenby and Toweill (1979) found a density of 2 plants/m^2 after 4 years on a seeded south-central Oregon Western juniper *(Juniperus occidentalis)* site. Kilcher and Heinrichs (1969) proposed that density of seeded alfalfa in semiarid regions reaches a balance with prevailing climatic regimes, the upper limit being determined by moisture stress conditions. Successful alfalfa reseeding has been reported in semiarid pasture seedings (Rumbaugh 1982). The lack of reproduction by seed observed in this study suggests that initial stand establishment is critical on semiarid pinyon-juniper sites. However, reseeding could have occurred in unsampled years between 1963 and 1967.

Severe rabbit damage has often been reported in rangeland alfalfa seedings (Tausch 1973, Lavin and Johnsen 1977, Phillips 1977, Johnsen and Gomm 1981). In this study, rabbits had occasional significant effects on alfalfa density at E. Mayfield and Mayfield Face. Observers reported unusually high jackrabbit populations at both sites for several years immediately after seeding. These results suggest rabbit use may not affect seeded alfalfa density when populations are below peak levels.

The effects of mule deer on survival of rangeland alfalfa have not been previously described. However, deer use of alfalfa is well documented (Kufeld et al. 1973). The results of this study are inconclusive, showing both positive and negative effects. This could be due to site differences as well as different levels of deer use. However, without replication of exclosures, further interpretation was not possible.

Comparisons between rabbit plus deer and rabbit plus deer plus livestock treatments are most useful, representing realistic management alternatives for rangeland seedings. Results suggest that the addition of intermittent early-season, short-duration livestock use may not increase alfalfa mortality above that induced by wild herbivores and environmental factors.

Variability in grazing treatment effects among sites may reflect different levels of herbivore use and/or site effects. This could not be tested, however, as herbivore use was not measured and exclosures were not replicated. In general, results of this study concur with those of Rumbaugh and Pedersen (1979), who found greater alfalfa survival under protection from grazing by rabbits, deer, and livestock.

The observed year × grazing treatment interactions suggest that the effects of herbivore use on alfalfa density vary with precipitation. Brownlee (1973) observed decreased alfalfa survival on dryland sites in Australia with increased grazing frequency. This effect was exacerbated by moisture stress. Rumbaugh and Pedersen (1979) also indicated that grazing-induced alfalfa mortality was compounded by drought. These year × grazing treatment interactions could also reflect year to year variation in herbivore use.

Production

Fluctuations in alfalfa production with changes in precipitation are typical on rangeland seedings. Similar variation has been reported for dryland sites in Saskatchewan (Campbell 1961) and pinyon-juniper sites in Utah (Phillips 1979). Alfalfa growth can show a strong positive response to increased moisture availability (Plummer et al. 1968).

Rabbit effects on alfalfa production approached significance only at Mayfield Face, where effects on stand density were also significant. This further suggests that the effects of rabbits alone were minimal, except at peak population levels. Deer use had a greater negative impact than rabbit use on production. The significant rabbit × deer interactions found at 2 sites indicate that the effects of these herbivores on alfalfa production may not operate independently.

The addition of livestock to native herbivore (rabbit and deer) use had a marked effect on alfalfa production. Significant declines were observed at 3 sites, all of which received frequent livestock use. Livestock effects were not significant at Manti Face, which received the longest post-seeding rest (12 years) and least frequent use. These results suggest that the frequency of livestock use is an important influence on alfalfa production.

Because livestock effects on production were not always significant, grazing was not necessarily deterimental. However, significant production decreases were observed in ungrazed periods following years with significant livestock effects, indicating that grazing-induced declines in alfalfa production can carry over from year to year.

There is little published information concerning grazing effects on production of rangeland seeded alfalfa. Results of this study concur with those of Brownlee (1973), who observed decreased production on Australian dryland sites with increased grazing frequency. Phillips (1979) also noted that alfalfa production on pinyon-juniper sites in Utah decreased from overuse by rabbits, deer, and cattle.

The presence of year × grazing treatment interactions suggests that herbivore effects on production are closely tied to precipitation. These interactions could also reflect year to year variation in herbivore use. The lack of significant year × livestock interactions at 2 sites indicates livestock effects may be independent of precipitation with infrequent grazing (Manti Face) or on sites with ≥46 cm annual rainfall (S. Hollow).

Growth Form

Differences among the grazing treatments indicate that wild and domestic herbivore use can have a significant effect on alfalfa growth form. The observed decrease in height and increase in basal cover with increased herbivore access could reflect selection or plasticity at the individual plant level. Of the 3 cultivars seeded, 2 are root proliferating (Nomad and Rambler), and the third (Ladak) is rhizomatous. However, a single strain can display a combination of growth patterns (Kehr et al. 1963).

Clipping studies by Carlson et al. (1964) and Gdara (1985) demonstrated that root proliferation was stimulated by defoliation. However, frequent, intense clipping decreased lateral shoot spread. A similar pattern was observed in this study. Basal cover per plant increased with increased wild herbivore access, but decreased under the added pressure of livestock use.

Prostrate growth form has frequently been associated with alfalfa survival under grazing (Heinrichs 1954, Kehr et al. 1963, Daday 1968). Two theories have been proposed to explain the higher survival of creeping alfalfa. Washko (1966) suggested that creepers with submerged crowns were capable of faster regrowth following defoliation and resistant to trampling damage during grazing. However, the adaptive value of rapid regrowth on semiarid sites is questionable. Berdahl et al. (1986) concluded that high regrowth potential was not conducive to long-term alfalfa persistence under grazing. Gdara (1985) proposed that the persistence of creeping plants reflected their ability to evade complete defoliation. Tall tap rooted plants were more likely to have all stems grazed to ground level than creepers with greater spread and a higher number of stems. Results of this study appear to support the latter hypothesis. Increased basal cover per plant was observed in the rabbit, deer, and rabbit plus dear treatments, which were not subjected to trampling by livestock.

Management Implications

Results of this study show that with proper management, alfalfa can be an important and persistent component of seeding mixtures used on semiarid pinyon-juniper ranges. The lack of reproduction by seed indicates that initial stand establishment is of critical importance. Alfalfa production is closely tied to precipitation, and generally decreases with increased grazing pressure. Long-term management of alfalfa seedings should include close monitoring of stand condition and livestock use. Use of cultivars with a prostrate growth form may enhance stand longevity.

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