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Mesquite Removal and Mulching Impacts on Herbage Production on a Semidesert Grass-Shrub Rangeland

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Abstract

The objectives of our study were to determine the effects of velvet mesquite (*Prosopis velutina*) removal, control of the resulting basal sprouts, and mulching treatments on herbage production (standing biomass) and selected soil chemicals (nutrients) shown to affect herbage production on the Santa Rita Experimental Range. Mesquite control treatments consisted of overstory removal by chain saw with and without control of the resulting basal sprouts. Mulching treatments were applications of mesquite wood chips, commercial compost, or lopped-and-scattered mesquite branchwood. Mesquite removal resulted in increases for total herbage production and the production of native herbaceous species. Production of the nonnative Lehmann lovegrass (*Eragrostis lehmanniana*), the dominant herbaceous species, was unchanged. The mulching treatments did not affect herbage production. None of the treatments affected soil chemical properties thought to influence herbage production.

Keywords: herbage production, mesquite removal, mulching treatments, soil chemical properties

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Cover photo: Velvet mesquite (*Prosopis velutina*) and intermingling grasslands, shown here on the Santa Rita Experimental Range in southern Arizona, are found throughout semidesert grass-shrub rangelands.

Mesquite Removal and Mulching Impacts on Herbage Production on a Semidesert Grass-Shrub Rangeland

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Introduction

Invasion of woody plants such as mesquite (*Prosopis* spp.) onto semidesert grass-shrub rangelands has been a long-time concern of rangeland managers and ranchers in the southwestern United States, because this encroachment reduces herbaceous (forage) resources and livestock production (Herbel and others 1983, Heitschmidt and Dowhower 1991, Martin and Morton 1993, Laxson and others 1997, McClaran 2003). The increase of mesquite has been attributed to varying combinations of earlier overgrazing by livestock, spread of seed in animal feces, reduced frequency of fire, and changes in climatic patterns (Fisher and others 1973, Martin 1975, Herbel 1979, McPherson 1997, Kramp and others 1998). One reason that the Santa Rita Experimental Range was established in southern Arizona 100 years ago was to evaluate methods of restoring degraded rangeland to higher levels of productivity. Among the methods tested was controlling the invasion of mesquite.

We conducted this study to estimate changes in herbage production (standing biomass) following the removal of the mesquite overstory with and without control of the resulting basal sprouts; the addition of mulch to conserve soil water and possibly improve the soil nutrient status; and combinations of these treatments. Another study objective was to determine whether the mesquite removal and mulching

treatments affected soil chemical properties thought to have an impact on herbage production.

Study Area

Our study was conducted on the nearly 50,000-acre Santa Rita Experimental Range, the oldest continuously operating rangeland research facility in the United States (McClaran and others 2003). Located about 40 miles south of Tucson, Arizona, the research site is situated on the western alluvial fan of the Santa Rita Mountains (Severson and Medina 1981, Medina 1996, McClaran and others 2003). Elevations range from 2,960 to 4,600 ft, while average annual precipitation increases along this gradient from about 10 to almost 18 inches. There are two main precipitation seasons on the Santa Rita Experimental Range, with summer (early July through the middle of September) and winter (early November through late March) precipitation averaging about 8.4 and 6.3 inches, respectively, since 1922. The physiognomy of the Santa Rita Experimental Range transitions from desert scrub communities at the lowest elevations to savanna woodlands at the highest elevations. The most extensive vegetative community is a mesquite-grassland savanna (fig. 1). Soils are typical of those found elsewhere on semidesert grass-shrub rangelands in the southwestern United States (McClaran and others 2003). Mesa and upland soils are

Figure 1—A mesquite-grassland savanna on the Santa Rita Experimental Range. The nonnative Lehmann lovegrass (*Eragrostis lehmanniana*) is the dominant herbaceous species in the community.



generally light, comparatively shallow, and underlain by caliche, while calcareous soils—also often underlain by caliche—are common on the more lowland sites on the Santa Rita Experimental Range. Valley bottoms tend to be filled with deep soils of alluvial origin.

Our study area was the Desert Grassland Enclosure on the Santa Rita Experimental Range, an area that had not been grazed by livestock for 70 or more years. Velvet mesquite (*Prosopis velutina*) dominates the woody overstory in the enclosure, while the nonnative Lehmann lovegrass (*Eragrostis lehmanniana*), a species initially planted on the Santa Rita Experimental Range in 1937 (Cable 1971, Ruyle and Cox 1985, Cox and Roundy 1986), is the main herbaceous species. Perennial native grasses include Arizona cottontop (*Digitaria californica*), spidergrass (*Aristida ternipes* var. *gentilis*), and curly-mesquite (*Hilaria belangeri*). Redstem stork's bill (*Erodium cicutarium*), Gordon's bladderpod (*Lesquerella gordonii*), and lupine (*Lupinus* spp.) are the principal forbs on the study area. Needle grama (*Bouteloua aristidoides*) and sixweek threeawn (*Aristida adscensionis*) are the most common summer annual grasses. There are two growing seasons for herbaceous plants. One season is early spring when temperatures and antecedent soil water derived from winter precipitation are favorable to plant species that are early growers. The second season is late summer and early autumn when plant species that are late growers respond to the summer monsoonal rains.

Annual precipitation in the 4-year study period of 1996 to 1999 was nearly one-third below the long-term average on the Santa Rita Experimental Range (McClaran and others 2003). The results of our study, therefore, provide information on the impacts of mesquite removal and mulching treatments on herbage production on a semi-arid grass-shrub rangeland suffering moderate drought conditions. The White House soils characterizing the study area are fine, mixed, superactive, thermic Ustic Haplargids (Breckenfeld and Robinett 2003). A typical profile of these soils has a 2 inch brown sandy-loam surface layer (A) with 5 to 15 percent surface gravel, while the subsoil (Bt, C) is a

brown to dark reddish clay to clay loam with a variable depth of 2 to 60 inches.

Data Collection and Analysis

Our study was arranged as a completely randomized design consisting of 60 15- by-15-ft square plots with a mesquite tree or shrub in the center of each plot and a minimum 5-ft buffer between the plots. The plots were blocked on the basis of information obtained from a pre-treatment inventory that indicated the structure (tree or shrub) and size (diameters at root collar 2 to 6 inches, heights 4 to 8 ft) of the mesquite plants on the study area. We randomly assigned treatments to the plots to ensure that the inventoried range of mesquite structures and sizes would be included within each treatment combination.

In July 1995, three mesquite removal treatments and four mulching treatments were applied within each of the overstory treatments. Each combination of a mesquite removal treatment and a mulching treatment was replicated five times. The overstory treatments were the (1) chain-saw removal of the mesquite tree or shrub with control of the resulting basal sprouts by hand-cutting in July 1997, (2) chain-saw removal of the mesquite tree or shrub without control of the resulting basal sprouts by hand-cutting, and (3) an untreated control. The mulching treatments included (1) applications of chip mulch, (2) a commercial compost, (3) lopped-and-scattered mesquite branchwood, and (4) no mulch. The chip mulch, obtained by chipping mesquite branchwood with a commercial chipper to a diameter of 0.5 inch or less was uniformly distributed on the plots to an average height of 1 inch above the soil surface. The commercial compost was fir-based with 0.5 percent nitrogen, 0.1 percent iron, and 0.2 percent sulfur. Approximately 10 ft³ of the compost was uniformly applied to each plot selected for this treatment (fig. 2). The mulch of lopped-and-scattered mesquite branchwood was spread to uniformly cover the plot to a height of approximately 6 inches.



Figure 2—A uniform application of 10 ft³ of a commercial fir-based compost on selected plots was one of the mulching treatments tested in our study.

The weight-estimate method (Pechanec and Pickford 1937) was used to initiate estimates of herbage production (standing biomass) by species on 9.6 ft² plots in late spring following the mesquite removal and mulching treatments. Overall, herbage estimates were made in May and October from 1996 to 1999. The two annual estimates, representing the production of early and late growers, respectively, were added to estimate annual production (biomass) of the herbaceous components studied for each of the 4 years in the study. Subsamples of herbage were collected to develop correction factors to convert the ocular field estimates to actual herbage production. These subsamples were dried, weighed, and extrapolated to pounds per acre.

Soil chemical properties that have been shown to affect herbage production on the Santa Rita Experimental Range—total nitrogen, nitrate, total organic carbon, total phosphorus, plant-available phosphorus (Olsen method), and pH (Paulsen 1953, Tiedemann and Klemmedson 1973, 1977, Klemmedson and Barth 1975, Subirge 1983, McClaran and others 2003)—were measured annually in late May or early June. A composite of 12 samples was obtained from the upper 2 inches of the soil profile at 1-ft intervals along a diagonal transect across each plot. These samples were analyzed in the Soil, Water, Plant Analysis Laboratory at the University of Arizona, Tucson.

Estimates of herbage production and soil chemical properties were subjected to analyses of variance to determine whether significant differences occurred in herbage production and selected soil chemical properties among the combinations of treatments. Tukey-Kramer HSD tests were used to separate treatment means where appropriate (Williams 1993). All statistical analyses were evaluated at a 10 percent level of significance.

Results and Discussion

Herbage Production

Total herbage production—consisting of about 90 percent perennials and 10 percent annuals—averaged $1,691 \pm 102$ lb/ac/yr ($\bar{x} \pm t_{0.10} \times \text{SE}$) annually from 1996 to 1999 on the plots receiving the two mesquite removal treatments. Control of the resulting basal sprouts had no effect on the herbage production. Herbage production on the untreated plots for the study period was $1,386 \pm 84$ lb/ac/yr. Reduced competition between mesquite and herbaceous plants for the available soil water likely contributed to the increase in total herbage production on the treated plots. However, the measured increase was less than that reported in earlier studies of herbage responses to the removal of mesquite (Herbel and others 1983, Heitschmidt and Dowhower 1991, Martin and Morton 1993, Laxson and others 1997). Only the tops of mesquite were removed in our study, while the entire mesquite plants were killed in the other studies. It was possible, therefore, that the mesquite plants in our study were still competing with herbaceous plants for soil water because their roots remained alive to produce the post-treatment basal sprouts.

Annual production of Lehmann lovegrass was analyzed separately because of the dominance of this species on the

study area (fig. 1). Mesquite removal treatments, either with or without control of the resulting basal sprouts, had no effect on the annual production of this species. The production of Lehmann lovegrass on all plots averaged $1,404 \pm 78$ lb/ac/yr annually for the study period. There was apparently only limited competition between mesquite and Lehmann lovegrass for the available soil water. Earlier research suggests that Lehmann lovegrass is capable of persisting and spreading in areas where precipitation within a 40-day summer period is 3.5 inches or more (Anable and others 1992) and that the species is adapted to surviving on sites where the total summer precipitation is 8 inches or more (Robinett 1992). While annual precipitation in our study was below the long-term average, production of Lehmann lovegrass might not have been constrained by a lack of summer soil water because summer precipitation in most years in this study was greater than the reported threshold amounts of precipitation that allow Lehmann lovegrass to thrive.

Annual production of native herbaceous species—both grasses and forbs—averaged 224 ± 42 lb/ac/yr on the plots receiving the mesquite removal treatments, either with or without control of the resulting basal sprouts, and 125 ± 18 lb/ac/yr on the untreated plots. The almost 80 percent increase in the production of native herbaceous species on plots where mesquite was removed suggests that the native species competed with mesquite for soil water and, therefore, responded positively to the removal of the mesquite overstories. The increase in light (solar radiation), a result of the reduction in overstory shade, could also have been a factor.

Earlier studies have shown that mesquite removal generally results in an increase in the production of both Lehmann lovegrass and native herbaceous species (Kincaid and others 1959, Cable and Tschirley 1961, Cable 1976, Martin and Morton 1993, McClaran and others 2003). However, the comparatively low level of precipitation throughout the period of our study helps to explain the discrepancy between the results of these cited studies and those reported here.

Mulching treatments had no impact on total herbage production, the production of Lehmann lovegrass, or the production of native herbaceous species (fig. 3). These results were attributed to the below-average annual precipitation for our study period, and the possibility that inadequate levels of mulch were applied to affect soil water availability and, therefore, plant growth. Biedenbender and Roundy (1996) suggested that mulching treatments might not affect available soil water in periods of low and infrequent rainfall and, in these instances, would not significantly affect the growth of herbaceous plants. It is also possible that, while the amount of mulch applied in our study might have reduced evaporation rates from the soil, interception of the limited rainfall amounts by the mulch layer that was applied could also have reduced the infiltration of water into the soil.

Determining the most effective layering of mulch to apply in attempting to conserve available soil water and possibly enhance the nutrient status of a soil is a difficult task (Lemon 1956). Insufficient amounts of mulching will likely not change evaporation enough to affect the soil water. On the other hand, excessive mulching can cause increases in soil temperature that can increase evaporation; it can also



Figure 3—A mulch of lopped-and-scattered mesquite branchwood (shown here) and the other mulching treatments tested had no impact on herbage production in our study.

increase interception of rainfall and, as a result, reduce infiltration of water into the soil.

None of the interactions between the mesquite removal treatments and mulching treatments were significant in their effects on herbage production.

Soil Chemical Properties

Neither the mesquite removal treatments—with or without control of the resulting basal sprouts—nor the mulching treatments significantly impacted the soil chemical properties that were evaluated. This result was not surprising, however, because of the comparatively slow rates of nutrient cycling and cellulose decomposition in semidesert grass-shrub ecosystems (Waring and Running 1998). While earlier studies on the Santa Rita Experimental Range examined the effects of standing mesquite overstories on soil chemical properties (Tiedemann and Klemmedson 1973, Barth and Klemmedson 1978, Virginia and Jarrell 1983), little research has been conducted on the effects of mesquite removal on soil chemical properties. However, Klemmedson and Tiedemann (1986) observed a decline in nutrient availability 13 years following the removal of mesquite. It is possible, therefore, that duration of our study was not long enough to measure the impacts of mesquite removal and mulching on the soil chemical properties that were evaluated. It is also likely that the drought conditions prevailing throughout the study contributed to the lack of significant changes in the soil chemical properties.

Interactions between the mesquite removal treatments and mulching treatments in relation to the selected soil chemical properties were not significant.

Conclusions

Chain-saw removal of mesquite trees and shrubs in our study increased total herbage production (standing biomass), a finding similar to the results of earlier studies. However,

control of basal sprouts by hand-cutting following mesquite removals had no effect on this increase. These sprouts could have been too small (<1.5 ft in height, <0.5 inches in diameter) when they were cut to influence the level of herbage production on the plots. Production of the nonnative Lehmann lovegrass was not affected by the mesquite removals, while production of native herbaceous species increased following removal of mesquite. The mulching treatments tested were ineffective in increasing annual production of the herbage species present on the study plots. Results from our study suggest that a treatment of top removal of mesquite, control of resulting basal sprouts, and addition of mulch to enhance the soil resource on semidesert grass-shrub rangelands that have predominantly Lehmann lovegrass understories might not increase herbage production enough to justify these treatments when conditions of drought are encountered.

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