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Season and Intensity of Burning on Two Grass Species of the Chihuahuan Desert

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Abstract

We investigated effects of three burning seasons under two simulated fuel loads on plant mortality and basal area of small and large blue grama (*Bouteloua gracilis* [H.B.K.] Lag) and broomgrass muhly (*Muhlenbergia rigida* [H.B.K.] Lag) plants in the southern Chihuahuan Desert of Mexico. We simulated prescribed fire with a portable propane burner calibrated to match time and temperature curves reached at 1 700 $kg \cdot ha^{-1}$ and 2 800 $kg \cdot ha^{-1}$ fine fuel loads. Large (initial basal area > 10 cm^2) and small (initial basal area ≤ 10 cm^2) plants were used. For each species, we randomly treated 50 plants in each size class each season at each fuel load; 50 control plants of each species and size received no fire treatment. We estimated basal area change from measurements recorded photographically. Blue grama mortality was affected by season of burning, simulated fuel load, and plant size. Small blue grama plants had higher mortality than large plants. Burning at the high fuel load in winter increased basal area of large blue grama plants; in contrast, basal area was not affected by summer burning, and was reduced by spring burning with high fuel load. Basal area of broomgrass muhly plants was reduced by summer and winter burning and these responses were independent of fuel load and plant size. Our results suggest that winter is the most suitable season for prescription burning to improve southern Chihuahuan Desert grasslands: prescribed fire during this time reduced basal area of broomgrass muhly plants, had the highest mortality on broomgrass muhly, had a positive effect on basal area of small blue grama plants, and had no effect on basal area of large blue grama plants.

Key Words: basal area, blue grama, broomgrass muhly, fire simulation, mortality, plant size

INTRODUCTION

In semiarid rangelands of the southern Chihuahuan Desert in Mexico, desirable grasses such as blue grama (*Bouteloua gracilis* [H.B.K.] Lag) and buffalograss (*Buchloe dactyloides* [Nutt.] J.T. Engelm.) are being replaced by broomgrass muhly (*Muhlenbergia rigida* [H.B.K.] Lag), a grass with poor nutritional quality (Adler and Morales 1999; Yeaton and Flores 2009) and invasive ecological behavior (Delgado-Balbuena et al. 2013) distributed mainly in the Mexican High Plateau and in some localized areas of the Chihuahuan Desert in Arizona, New Mexico, and Texas. There has been relatively little research about effects of season, frequency, and intensity of fire on grasses of the Chihuahuan Desert (Humphrey 1974; Ahlstrand 1982; White and Currie 1983) and almost nothing is known about fire effects on broomgrass muhly.

Reports of fire effects on muhly species generally are scarce. Although Wright (1980) suggested that bush muhly (*Muhlenbergia porteri* Scribn. ex Beal) may be seriously damaged by fire, Aleksoff (1999) indicated that this species responded favorably to fire because of its widely arranged culms. Fryer (2009) found that bush muhly was generally favored by dormant season burns during early spring and winter, and further, that muhly species increase their productivity after fire, a response commonly observed in many other warm season grasses (e.g., Risser et al. 1981; Wright and Bailey 1982). Steuter (1987) found that plains muhly (*Muhlenbergia cuspidata* [Torr. ex Hook.] Rydb.) remained unchanged or increased after spring burning; this response may be attributable to the fact that its growing points are buried and thus insulated by soil (Fryer 2009). Walsh (1995) reported that mountain muhly (*Muhlenbergia montana* [Nutt.] Hitchc.) decreased after burning and required 3 yr to recover in central Arizona.

Potential management practices for mitigating broomgrass muhly invasion in the southern Chihuahuan Desert of Mexico include prescribed burning. The objective of this study was to evaluate the main and interactive effects of season of burning (spring, summer, and winter), plant size (small and large plants), and simulated fuel load (low and high) on mortality and changes in basal area of blue grama and broomgrass muhly in the Chihuahuan Desert. We hypothesized that prescribed fire effects on broomgrass and blue grama mortality would be affected by season of burn (with higher mortality when burned in the summer), plant size (with higher mortality of smaller plants), and fuel load (with higher mortality at higher fuel loads); furthermore, we expected that highest mortality would be observed for small plants burned at the higher fuel load during summer. We used a fully replicated and randomized experiment conducted over 2 yr with 2 800 individually marked plants to address our objectives.

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Table 1. Monthly precipitation (mm) at Vaquerias Experimental Station in Jalisco State, Mexico.

Month	2005	2006	2007	Mean[1]
January	0.0	0.0	18.5	17.0
February	0.5	0.0	33.5	2.5
March	21.4	5.5	0.0	2.0
April	5.0	28.2	10.2	1.5
May	16.2	101.1	37.0	35.0
June	0.0	36.7	117.8	70.0
July	53.0	103.3	184.9	113.7
August	84.9	84.7	17.7	83.0
September	47.8	93.0	83.7	61.0
October	35.4	35.3	44.4	28.0
November	0.0	17.4	6.4	7.0
December	0.0	7.8	0.0	5.0
Total	264.2	513.0	554.1	430.0

[1]20-yr mean.

METHODS

The study was conducted on semiarid rangeland at the Vaquerias Experimental Station in the Los Llanos de Ojuelos subprovince of Mexico in the southern Chihuahuan Desert. Our study pasture had a history of 8 yr with no livestock grazing. Elevation at the site is 2 130 m above sea level, and soils are dominated by loams and sandy loams with a caliche layer at 50 cm. Topography is mainly flat with gentle slopes from 0% to 5%. Climate consists of warm summers and cool dry winters with average temperatures fluctuating from 16°C to 18°C; the average daily minimum and maximum temperatures are 4.5°C in January and 25°C in July (CETENAL 1970). Average annual precipitation is 430 mm, occurring mainly in summer. During this study we had 38% below, and 19% and 28% above average precipitation in 2005, 2006, and 2007, respectively (Table 1).

Vegetation in the study area is dominated by shortgrass species. Primary grasses are blue grama, wolftail (*Lycurus phleoides* H.B.K. Kunth), threeawn (*Aristida* spp. L.), needlegrass (*Microchloa kunthii* Desv.), and broomgrass muhly. There are also large populations of broomweed (*Haplopappus venetus vernonioides* cultivar *Isocoma* Kunth), brickellbush (*Brickellia spinulosa* A. Gray), pricklypear (*Opuntia streptacantha* Lemaire), and huisache (*Acacia farnesiana* [L.] Willd).

The experimental design was a completely randomized design with a factorial combination of three factors (plant size, season of burning, and fuel load) for each species. We defined two plant size classes based on initial basal area measurements: large and small plants had basal areas > 10 cm^2 and ≤ 10 cm^2, respectively. For each season of burning we randomly selected 50 plants of each size class for each simulated fuel load treatment for each species. Fuel load treatments were randomly assigned to plants. Because the study was conducted in native rangeland and plants were randomly selected, we placed no restrictions on distance between plants used in the experiment except that burn barrel placement did not overlap two target plants; ca. 90% of the target plants, however, were separated by 5 m to 10 m.

We simulated prescribed fire using a portable propane burner designed by Britton and Wright (1979) and calibrated using a series of combinations of gas pressure and time to obtain specific time temperature curves reached with 1 700 $\text{kg} \cdot \text{ha}^{-1}$ and 2 800 $\text{kg} \cdot \text{ha}^{-1}$ of fine fuel, as found in a typical prescribed burn (Wright et al. 1976). In the calibration process we generated the following prediction equation for temperature (°C): temperature$=-30.613+157.9x_1+5.7196x_2$, ($\hat{R}^2=0.881$), where x_1=gas pressure ($\text{kg} \cdot \text{cm}^{-2}$), and x_2=time (seconds). Temperatures of 143.4°C and 184.8°C for fuel loads of 1 700 $\text{kg} \cdot \text{ha}^{-1}$ and 2 800 $\text{kg} \cdot \text{ha}^{-1}$ were reached by burning with pressures of 10 psi for 11 s and 18 s for low and high fuel loads, respectively (Britton and Wright 1979). Plants were burned in spring (April), summer (June), and winter (December) of 2005 and 2006. Burned plants were marked with a painted nail and numbered tag for follow-up plant mortality and basal area evaluations. We also evaluated 50 nonburned control plants of each species and size class.

In autumn 2007, one growing season after fire treatments, we evaluated each plant for mortality, assuming plants with no live tillers to be dead. We assessed changes in basal area of living plants that were burned in 2006 by measuring total soil surface area covered by grass crown using photographic techniques (Owens et al. 1985; Britton et al. 1990; Roshier et al. 1997; Bennett et al. 2000; May et al. 2008). We took an overhead photo of each plant from a height of 1.5 m with a digital camera (Polaroid Foveon) immediately after burning (initial area) and again at the end of the following growing season (final area) to estimate percentage of change. To estimate basal area, we delineated the perimeter of each plant by wrapping it once with a steel chain (0.5 cm wide, 3 m long); we then placed a 70×50 cm grid over the plant crown (using the graduated sides [cm] as reference) and took a photo. Raw format was used because this separates the colors in the photo into layers rather than mixing them as is normally done in digital cameras. We analyzed photographs with Adobe Photoshop software: basal areas outlined by the chain were filled with a dull color, estimating the number of pixels. We converted this to area using a factor of 2 126 $\text{pixels} \cdot \text{cm}^{-2}$.

For each year, we analyzed data as a completely randomized design with a $2 \times 3 \times 2$ factorial arrangement of plant size, season, and fuel load. We used the Fisher's Protected LSD test to compare treatment means. We assessed normality assumptions with the Shapiro-Wilk (Shapiro and Wilk 1965) test and homogeneity of variance assumptions with Levene's (1960) test. Mortality data are binomial in nature; use of a generalized linear model, however, was not possible with these data because of quasi-complete separation (i.e., mortality responses largely separated treatments into their levels; Webb et al. 2004). Therefore, we analyzed mortality data with a general linear model (SAS 2010) and adjusted for heterogeneous variances following Brown and Forsythe (1974) to test our hypotheses listed above.

RESULTS

Blue Grama—Mortality

For plants burned in 2005 (a relatively dry year), plant size, fuel load, and season of burn acted independently of each other