THE RESPONSE OF OLD WORLD BLUESTEM TO MID- AND LATE-SUMMER FIRE IN TWO GRASSLAND ECOREGIONS IN CENTRAL TEXAS

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ABSTRACT

Old World bluestem (*Bothriochloa ischaemum*) is an invasive, nonnative, C_4 perennial grass that has become widespread throughout the southern United States. It is considered a problematic invader of fields and roadsides in north-central, central, and southern Texas. Although the growth of this species is enhanced by dormant-season prescribed fire, observations suggested that this species might prove sensitive to growing-season prescribed fire.

Identical suites of treatments were installed at two locations in central Texas representative of two grassland ecoregions: Edwards Plateau and Blackland Prairie. Frequency measurements taken during the growing season in the year following treatment demonstrated that *B. ischaemum* was significantly reduced at both Edwards Plateau ($F = 26.99$, $P < 0.0001$) and Blackland Prairie ($F = 27.11$, $P < 0.0001$) sites. The magnitude of the response was not consistent, however, with a reduced response at one site where there had been a significant rainfall immediately before and after the burn installation. We suggest that successful selective control of this species may be achieved by synchronizing growing-season prescribed fire during dry conditions.

keywords: Bothriochloa ischaemum, grassland, invasive, Old World bluestem, prairie, prescribed fire, Texas.

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INTRODUCTION

Old World (yellow or King Ranch) bluestem (*Bothriochloa ischaemum* var. *songarica*) is a C_4 (warm-season) perennial bunchgrass native to Asia and Central Europe that has become widespread throughout the southern United States since its introduction in the early 1900s (Gould 1978). Although the benefits of Old World bluestem as a cattle forage crop have been recently called into question (Coleman et al. 2001), it has been successfully used for livestock range improvement throughout the southern Great Plains (Coyne and Bradford 1984, Berg et al. 1996, Teague et al. 1996), including marginal rangeland in Oklahoma and Texas (Berg 1993, Welch et al. 2001). Although the precise distribution has not been quantified, Old World bluestem is presently considered a problematic invader of temperate grasslands in North America (Grace et al. 2001, Harmoney et al. 2004) and of roadsides in north-central (Diggs et al. 1999), central, and southern Texas (Union of Concerned Scientists 2003). Typical of other invasive exotic species, Old World bluestem has the ability to crowd out native plants (Diggs et al. 1999), threaten rare native plant species (Union of Concerned Scientists 2003), and suppress insect and small-mammal diversity (Schwertner 1996, Mcintyre and Thompson 2003).

The spread of Old World bluestem into native

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grasslands has been the result of the combination of widespread agricultural and roadside seeding (Gould 1975), negative grazing selection by livestock, its relative ease of establishment, and ability to successfully compete with native grasses over the long term (Eck and Sims 1984, Berg 1993). Old World bluestem is a highly stress-tolerant C_4 grass, with high carbon balance and water use efficiency under marginal abiotic conditions of low moisture and nitrogen (Szente et al. 1996). Under grazing pressure, this species allocates more resources to basal structures and switches from an upright to more prostrate form (Campanella 1977). However, it does exhibit sensitivity to interspecific competition under continual grazing or mowing (Szente et al. 1996) and drought sensitivity in the seedling stage (Berg et al. 1996). Additionally, there have been indications that while dormant-season (winter) fire may increase production of Old World bluestem in the subsequent growing season (Pase 1971), early growing-season (spring) fire can have a negative effect on growth (Berg 1993).

Studies examining the responses of plant populations to seasonality of fire in grasslands are sparse and somewhat inconclusive (Towne and Owensby 1984, Glenn-Lewin et al. 1990, Howe 1994*b*, Engle and Bidwell 2001). However, what emerges is that although many species seem unaffected by fire seasonality, those that are sensitive demonstrate species-specific rather than guild-level (C_3 grass, C_4 grass, summer forb, etc.) responses (Wright and Klemmedson 1965, Mayeux and Hamilton 1988, Howe 1994*b*, Kush et al. 1998, Sparks et al. 1998). These differential responses suggest that utilization of seasonally applied prescribed fire need not negatively impact the growth of all species within the plant community, or even all species within a single guild. Therefore, seasonally applied prescribed fire could be used as a selective filter for the removal of unwanted sensitive species.

The objective of this study was to evaluate the effectiveness of mid- and late-growing season fire for suppressing the growth of Old World bluestem on sites representative of two Texas grassland ecoregions: Blackland Prairie and Edwards Plateau.

STUDY AREA

Two sites in Texas were selected for this treatment: one representative of Blackland Prairie and the other representative of the Edwards Plateau ecoregion. The Blackland Prairie site was located at the San Marcos National Fish Hatchery and Technology Center in San Marcos, Texas (29°50′15″N, 97°58′45″W; elevation 300 m). Soils were fine, montmorillonitic, thermic Udic Pellusterts of the Houston Black series, characteristic of upland Blackland Prairie in central Texas (USDA 1984). The site was donated to the U.S. Fish and Wildlife Service in the 1960s; however, its prior management history is unknown. Prior to treatment, the pasture was largely dominated by Old World bluestem (39% cover) and silver bluestem (*B. laguroides*) (19%), with a mixture of native and nonnative forbs. The Edwards Plateau study site was at the Lyndon B. Johnson National Historical Park, Johnson City, Texas (30°16′16″N, 98°25′02″W; elevation 375 m). Soils were very fine, montmorillonitic, thermic Udic Chromusterts of the Anhalt series, which are limestone-derived clayey soils typical of flat upland sites on the Edwards Plateau (USDA 1979). The area had been maintained as rotated cattle pasture for the last decade. Dominant grasses included Old World bluestem (55%), Texas wintergrass (*Nassella leucotricha*) (16%), and meadow dropseed (*Sporobolus compositus*) (16%). Taxonomic nomenclature follows Kartesz (1999).

The climate for both sites was subtropical, subhumid: mild winters and hot summers with a bimodal (May and September) rainfall pattern. The 30-y, monthly mean temperature range and average annual rainfall were 16.2–35.2°C and 878 mm, respectively, for the Blackland Prairie site, and 4.5–35.6°C and 844 mm, respectively, for the Edwards Plateau site. Climate data were obtained through National Weather Service database and from observation from nearby weather stations.

METHODS

Five replicates of three treatments (mid- and late growing-season fire and no fire) were installed at both sites following a randomized plot design. Each experimental unit measured 15 × 15 m, separated by a 10-m mowed boundary used for accessibility and to serve as a firebreak. All experimental units were ignited using ring-firing technique following wet lining along the firebreaks. Weather parameters were taken on-site using belt weather kits.

Species canopy frequency of all species was assessed using a single diagonal, corner-to-corner transect for each experimental unit, with point-intercept readings taken every 1 m (20 points per unit). Only living vegetative or reproductive tillers were recorded. Frequency of Old World bluestem and other dominant species was measured prior to treatment (May 2004) and again the following year (May 2005). The effect of treatment on frequency of Old World bluestem was examined with analysis of covariance, with pre-treatment species frequency as the covariable. Although other species within the plant communities at both sites had low or patchy distributions, Texas wintergrass and meadow dropseed had adequate occurrences (i.e., with few null data points) to also allow parametric analysis. Tukey multiple comparisons were used to test for differences between means. An alpha of 0.05 was used throughout.

RESULTS

In central Texas the growing season for Old World bluestem and for most C_4 grasses extends from mid-May through to mid-November in a normal year (Gould 1975). The timing of mid- and late growing-season prescribed fire was dictated by weather and lo-

Table 1. Weather, rainfall patterns, and fuel conditions for mid- and late growing-season prescribed fires conducted at Blackland Prairie and Edwards Plateau sites, central Texas, during 2004.

						Cumulative rainfall (mm)						
			Mean air temperature	Eye-level wind speed	Mean relative humidity	No. days pre-burn			No. days post-burn			Fine fuel load range
Site	Season	Date	(°C)	($km\ h^{-1}$)	(%)	5	10	20	5	10	20	($kg\ ha^{-1}$)
Blackland Prairie	Mid-season	13 Aug	32	8–16	80	1	2	28	0	8	40	1,900–2,400
	Late-season	8 Nov	26	5–11	60	0	36	121	0	110	112	1,900–2,400
Edwards Plateau	Mid-season	25 Aug	31	8–16	65	8	21	47	3	48	51	1,200–1,900
	Late-season	28 Oct	28	10–13	50	61	65	94	69	71	71	1,200–1,900

gistical constraints, such that the burn events in a given season were not coincident for Blackland Prairie and Edwards Plateau sites (Table 1). However the conditions for each prescribed fire were somewhat similar in terms of temperature, wind, and humidity (Table 1), with low-intensity fire fronts with flame heights <1 m but >90% total canopy burn. Fine fuel loads (visually estimated) were different both among experimental units and particularly between sites. Lower fuel loads at the Edwards Plateau site were considered to be a result of only 6 months' rest from moderate grazing pressure (Table 1). Although annual rainfall totals for both sites through the experimental period (4–5 May) were similar (Backland Prairie: 1,299 mm; Edwards Plateau: 1,290 mm), rainfall totals during the days immediately prior to and after fire installation were variable (Table 1). The late-season prescribed fire at the Edwards Plateau site experienced relatively high cumulative rainfall during the 5 d before (61 mm) and after (69 mm) the day of the burn (Table 1). All other sites experienced <10 mm for the same time intervals before and after the burn (Table 1). Three of the four burn treatments reduced cover of Old World bluestem from 60–70% to <10% canopy cover. However, the late growing-season treatment at the Edwards Plateau site exhibited a reduced response of only 34% (Figure 1). Analysis of the other two subdominant species, Texas wintergrass and meadow dropseed, indicated neither a positive or negative response to treatment (data not shown).

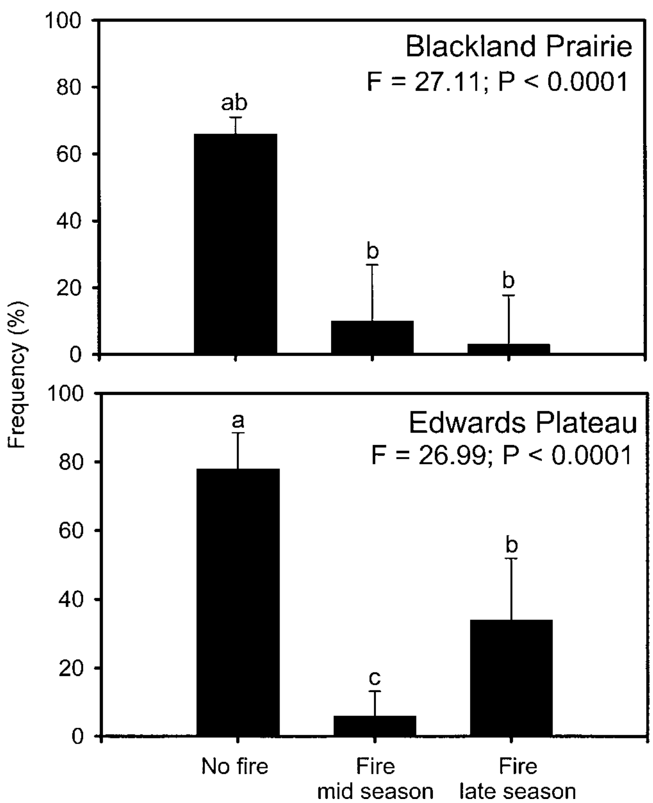

Fig. 1. Canopy cover response of Old World bluestem to mid- and late growing-season fire at Blackland Prairie (top) and Edwards Plateau (bottom) sites, central Texas, 2004. Error bars represent 95% confidence limits. Bars with different letters have means that are significantly different at $P < 0.05$.

DISCUSSION

Prescribed fire applied during the growing season resulted in reduced canopy cover of Old World bluestem in the following year (Figure 1). However, the magnitude of the response was not consistent, with the late-season fire at the Edwards Plateau site having a reduced effect. Elsewhere, variation in plant mortality has been attributed to the coincidence of fire characteristics and plant resource allocation patterns (Wright and Klemmedson 1965, McDaniel et al. 1997). We suggest that the reduced impact of the fire on one out of four treatments was a consequence of significant rain events immediately before and after the fire event. Fire intensity may have been reduced by higher dead fuel moisture, enhanced water status of the target species may have reduced tissue damage during the fire, or damaged plant individuals may have been more likely to recover due to high soil moisture after burning (Table 1; Figure 2).

Fire can directly affect individual growth and regeneration conditions negatively or positively (Baruch and Bilbao 1999) by influencing post-disturbance conditions and competitive species interactions (Hartnett 1991, Bond and van Wilgen 1996, Suding 2001). The direct effects of fire, such as tissue and whole-plant death, are complex, with many biotic and abiotic variables (Bond and van Wilgen 1996). In general, theory suggests that an individual plant is more likely to benefit from the various fire effects if the timing is asynchronous with the plant's active stages of growth when the risk of living tissue damage is reduced (Howe 1994*b*, Copeland et al. 2002). The converse argument—that growing-season fire will negatively affect plant growth—is not necessarily true. Species sensitivity to fire during the growth phase is species-specific

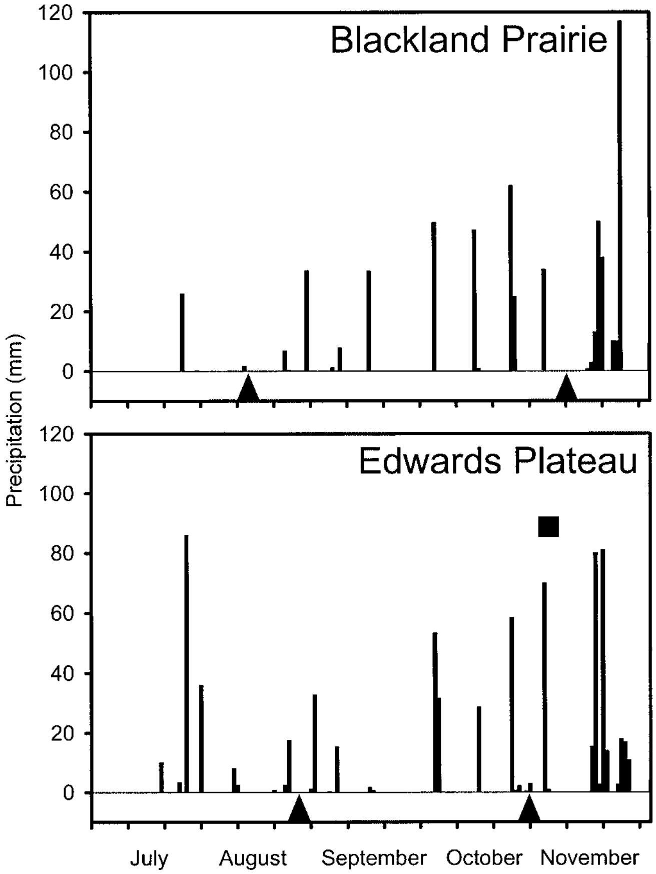

Fig. 2. Daily precipitation during the 2004 growing season at Blackland Prairie (top) and Edwards Plateau (bottom) sites, central Texas. Solid triangles indicate the days of prescribed burns.

and may be negative, neutral, or positive (Wright and Klemmedson 1965, Frost and Robertson 1985, Howe 1994*a*, Whelan 1995, Bond and van Wilgen 1996). Although some studies have indicated that grass mortality is reduced in more mesic sites (Zedler and Loucks 1969) and during wetter years (Frost and Robertson 1985), there seems no direct evidence for the mechanism explaining the variation of tissue damage due to available water. An understanding of the mechanism would help application of this technique and aid prediction of grass responses for years with different precipitation patterns.

Regardless of mechanism, and given the limited time period of the experiment, the target species in this study appears to have been prone to fire damage during the mid- and late growing season, which is in sharp contrast to the effect of dormant-season fire (Pase 1971). The neutral response from Texas wintergrass and meadow dropseed may support the hypothesis that many grassland species are fire adapted. Alternatively, this phenomenon may be a simply a artifact of low occurrence of these species. Given that many other dominant native perennial grass species in Great Plains grasslands have demonstrated positive or indifferent response following growing-season fire (Towne and Owensby 1984, Sparks et al. 1998), this study indicates growing-season fire may be used to selectively reduce undesirable invasive species without eliciting a detrimental response in desirable native species.

MANAGEMENT IMPLICATIONS

Theory concerning the responses of grassland species to fire has been largely based on the results of dormant-season prescribed fire. Consequently, it is not uncommon for land practitioners to conclude that fire responses in grasses are consistent regardless of season. We suggest that such generalizations of plant guild response to fire may be inaccurate and species-specific responses to fire season require further examination. Understanding these fires' response characteristics may have particular significance for control of invasive species in grasslands.

Species response to fire may depend on timing with respect to climate and phenological stage of the individual plant. Although Old World bluestem is suppressed by growing-season fire, many native grasses are not. Therefore, timely application of growing-season prescribed fire offers an alternative to other control methods, which can help land managers selectively control the spread of this invasive species while sustaining more desirable native grasses.

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