



Mesquite (*Prosopis*) seedling responses to fire and grass production in the southern Great Plains, USA

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Abstract

Prescribed fire is an economical land management practice used to mitigate the global increase in woody plant encroachment (WPE) on rangelands. For woody plants that resprout following fire, the seedling stage may be vulnerable to fire. However, we know little about long-term growth of mesquite seedlings that survive fires. We measured seedling survival and post-fire gains in canopy cover of two cohorts (seeds planted in two different years) of honey mesquite (*Prosopis glandulosa*) seedlings in response to winter or summer fires in mixed-grass (~2,000 kg/ha) or tallgrass (~7,000 kg/ha) fuel types in the Southern Great Plains, USA. Post-fire seedling survival was highest to lowest in no fire, winter fire and summer fire, respectively, in both grass types and seedling cohorts. Canopy cover in all fire treatments and both cohorts increased to a greater level in mixed-grass than tallgrass over a 20-year period. Fire treatment had little effect on post-fire canopy cover gains. Rate of cover gain in mixed-grass (3.4 percentage units per year: PU/yr) was greater than a previously reported rate of 2.2 PU/yr for mature mesquite over 20 years at the same site. Lower mesquite seedling growth in tallgrass plots was likely due to a combination of greater pre-fire mortality, greater mortality from more intense fires, and greater post-fire grass competition for resources. Results suggest that mixed-grass, which is the dominant grass type in the region, may not be sufficiently competitive to slow the rate of mesquite seedling growth even after summer fire.

Introduction

Fire was an integral part of pre-settlement grasslands and rangelands in the southern Great Plains (SGP), USA and likely suppressed the expansion of woody plants (Briggs et al. 2005, Guyette et al. 2012). After European settlement, many woody species, including the fire-resistant native woody legume, honey mesquite (*Prosopis glandulosa* Torr.), expanded in density and distribution; due in part to the reduction of fire frequency that limited mesquite seedling establishment (Archer et al. 1995, 2017). In addition, cattle consumption and fecal deposition of viable mesquite seeds enhanced distribution (Brown and Archer 1987, Ansley et al. 2017).

Adult mesquite plants resprout following top-kill and very few are root-killed by fire (Ansley et al. 2021). However, seedlings are vulnerable to fire for a brief period of time (Wright et al. 1976). Productive stands of grass can reduce growth rate of young mesquite (Brown and Archer 1989, Van Auken and Bush 1990). However, we know little about long-term growth of mesquite seedlings that survive fires. Ansley et al. (2015) quantified mortality of mesquite seedlings when burned with summer or winter fires in mixed-grass and tallgrass fuel types and found that summer fires in both grass types and winter fires in tallgrass increased seedling mortality compared to no fire. Our objective here was to quantify long-term (20-year) growth of those seedlings that survived the fire treatments.

Methods

We conducted the study within a fenced pasture on a private ranch in north Texas. We included two patches of native mixed-grass and two patches of tallgrass. Each patch was 2.7 ha in size. The mixed-grass patches were mostly comprised of Texas wintergrass (*Nassella leucotricha*) and buffalograss (*Buchloe dactyloides*), with a small proportion of C₄ mid-grasses such as sideoats grama (*Bouteloua curtipendula*) (average standing biomass ~2,000 kg/ha). The tallgrass patches consisted of introduced kleingrass (*Panicum coloratum*) planted in the 1970's (~7,000 kg/ha). All grass patches occurred on the same Tillman clay loam soil type (Ansley et al. 2015).

We hand-planted 924 mesquite seeds in each of twelve 0.125 ha plots in one mixed-grass and one tallgrass patch in April 1997 (hereafter Cohort-97), and repeated the procedure in the second of each patch in April 1998 (Cohort-98). We established three treatments (no fire, winter fire and summer fire) in each grass patch with four replicate plots per treatment. Seedlings were 17 months old during summer fires and 10 (Cohort-97) or 22 (Cohort-98) months old during winter fires. We did not apply winter fire to 10-month-old Cohort-98 seedlings due to drought and insufficient grass fuel and instead winter burned the following year. No further fires occurred after the year 2000. We excluded livestock grazing during the study period. More details are in Ansley et al. (2015).

We obtained aerial images of the plots in the years 2000, 2002, 2012 and 2019 that provided excellent contrast between mesquite and grass cover and visually estimated mesquite canopy cover in each plot each year. We analyzed canopy cover responses to fire treatments within each grass patch using the PROC MIXED procedure in SAS with fire treatment and time post-fire as main effects with four replicate plots per treatment (SAS 2013). We separated means using LSD at $P \leq 0.05$.

Results

Percent seedling survival and number of live seedlings per plot at 1 year after all fire treatments were highest in no fire, mixed-grass for both cohorts and lowest in the summer fire treatment within each cohort and grass type (Table 1).

Mesquite canopy cover of Cohort-97 in mixed-grass increased at similar rates in the three treatments and reached 65-75% by 2019 (Figure 1A). Cohort-97 cover in tallgrass increased at similar rates among the three treatments but only reached 25-33% canopy cover by 2019. Similar responses were found with Cohort-98 seedlings except that canopy cover gain in mixed-grass was slightly lower in the summer fire than the winter fire treatment by 2019, with no fire intermediate (Figure 1B).

Table 1. Mesquite seedling cohort, land patch, grass type, fire treatment season and year, seedling age at the time of fire treatment, and average percent seedling survival and number of live seedlings the first growing season after all fires were completed.

Seedling Cohort	Land Patch	Grass Type	Fire Season and Year ¹	Age when Burned (Months)	Post-fire Percent Seedling Survival	Live Seedlings Per Plot Post-Fire
Cohort-97	1	Mixed	No Fire	---	7.2	67
Cohort-97	1	Mixed	w-1998	10	5.5	51
Cohort-97	1	Mixed	s-1998	17	2.0	19
Cohort-97	2	Tallgrass	No Fire	---	1.9	17
Cohort-97	2	Tallgrass	w-1998	10	2.1	19
Cohort-97	2	Tallgrass	s-1998	17	0.8	8
Cohort-98	3	Mixed	No Fire	---	7.3	67
Cohort-98	3	Mixed	s-1999	17	3.1	28
Cohort-98	3	Mixed	w-2000	22	5.4	50
Cohort-98	4	Tallgrass	No Fire	---	5.4	50
Cohort-98	4	Tallgrass	s-1999	17	2.3	22
Cohort-98	4	Tallgrass	w-2000	22	3.8	35

¹/ w = winter fire; s = summer fire

Discussion

Even though the fire treatments reduced the starting number of live mesquite seedlings compared to no fire, this had minimal effect on post-fire gains in canopy cover. The only exception occurred in the Cohort-98 mixed-grass patch where summer fire reduced canopy cover gain over time compared to winter fire. A spike in growth in all treatments between 2000 and 2002 was more pronounced with Cohort-97 than the 1-year younger Cohort-98 seedlings and this may have affected differences seen in 2019. Growing season precipitation was well above normal in 2002 (Ansley et al. 2021) and Cohort-97, being 1 year older, may have been able to exploit the enhanced soil moisture across all fire treatments more effectively than Cohort-98.

Largest gains in canopy cover came from Cohort-97 in the mixed-grass type. Averaged over the 3 treatments, canopy cover reached 68% over 20 years, or a rate of cover increase of 3.4 percentage units per year: PU/yr). Rate of gain for Cohort-98 in mixed-grass was similar to Cohort-97; 60% over 19 years (2000 to 2019), or 3.2 PU/yr. These rates of cover gain are greater than a previously reported rate of 2.2 PU/yr for mature mesquite over 20 years at the same site (Ansley et al. 2001). A lower rate of cover gain with mature mesquite suggests that the growth rate slows with age, but results from the current study show this decline in growth rate may not occur within the first 20 years of growth.

Slower mesquite growth in tallgrass was likely due to a combination of greater pre-fire seedling mortality due to tall grass competition (Van Auken and Bush 1990), greater mortality from more intense fires (Ansley et al. 2015), and greater post-fire grass competition for resources. Results suggest that mixed-grass stands that have degraded to lower producing species such as Texas wintergrass and buffalograss may not be sufficiently competitive to slow the rate of mesquite seedling growth even after summer fire and (in this study) under no livestock grazing pressure. However, results from the tallgrass patches suggest that mixed-

grass stands that have a greater proportion of more productive C₄ mid-grass species than found in our mixed-grass stands might provide greater long-term resistance to mesquite seedling recruitment and growth.

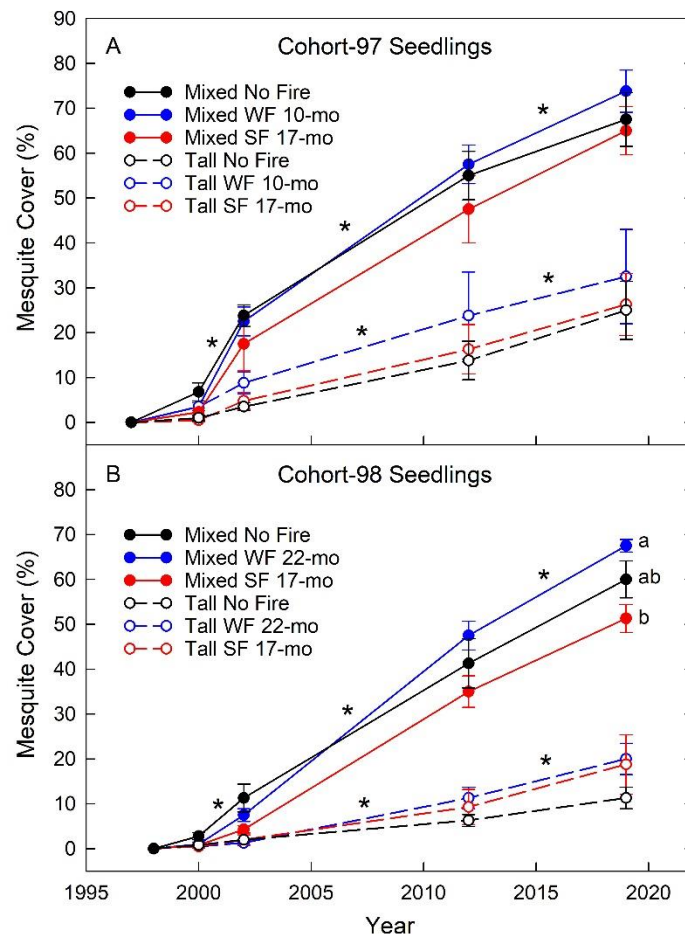


Figure 1. Change in mesquite cover from seedlings of Cohort-97 (A) or Cohort-98 (B) in mixed-grass (Mixed) and tallgrass (Tall) when exposed to no fire, winter fire (WF) at 10-months (Cohort-97) or 22-months (Cohort-98) of age, or summer fire (SF) at 17 months of age. Vertical lines are ± 1 standard error. Means with similar letters within each grass type and year are not significantly different ($P \leq 0.05$). An asterisk indicates a significant ($P \leq 0.05$) difference from one time period to the next when averaged over the 3 treatments in each grass type. There were no significant differences among fire treatments within each grass type in any year.

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